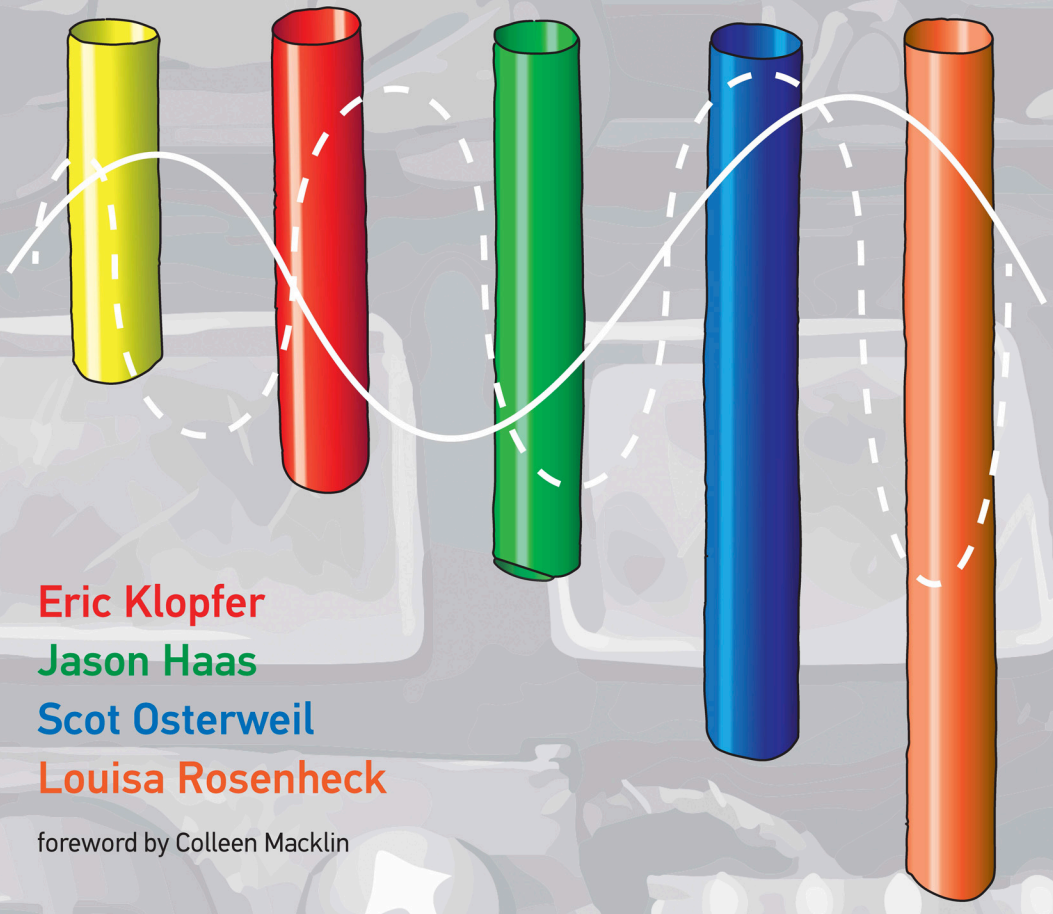
Resonant Games

Design Principles for Learning Games that Connect Hearts, Minds, and the Everyday



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foreword by Colleen Macklin

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Resonant Games

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Eric Klopfer, Jason Haas, Scot Osterweil, and Louisa Rosenheck

The MIT Press
Cambridge, Massachusetts
London, England

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Illustrations on pages 18, 19, 20, 73, 94, 196, 211, 212, 216, 225, and 226 by Brett Paci.

This book was set in ITC Stone Sans Std and ITC Stone Serif Std by Toppan Best-set Premedia Limited. Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Names: Klopfer, Eric, author.
Title: Resonant games : design principles for learning games that connect hearts, minds, and the everyday / Eric Klopfer, Jason Haas, Scot Osterweil, and Louisa Rosenheck ; foreword by Colleen Macklin.
Description: Cambridge, MA : MIT Press, [2018] | Series: The John D. and Catherine T. MacArthur Foundation series on digital media and learning | Includes bibliographical references and index.
Identifiers: LCCN 2017038913 | ISBN 9780262037808 (hardcover : alk. paper)
Subjects: LCSH: Video games in education. | Education Arcade (Project)
Classification: LCC LB1028.75 .K56 2018 | DDC 371.33/7--dc23 LC record available at https://lccn.loc.gov/2017038913

10 9 8 7 6 5 4 3 2 1

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Series Foreword

In recent years, digital media and networks have become embedded in our everyday lives, and are part of broad-based changes to how we engage in knowledge production, communication, and creative expression. Unlike the early years in the development of computers and computer-based media, digital media are now *commonplace* and *pervasive*, having been taken up by a wide range of individuals and institutions in all walks of life. Digital media have escaped the boundaries of professional and formal practice, and the academic, governmental, and industry homes that initially fostered their development. Now, diverse populations and noninstitutionalized practices, including the peer activities of youths, have embraced them. Although specific forms of technology uptake are highly diverse, a generation is growing up in an era when digital media are part of the taken-for-granted social and cultural fabric of learning, play, and social communication.

This book series is founded on the working hypothesis that those immersed in new digital tools and networks are engaged in an unprecedented exploration of language, games, social interaction, problem solving, and self-directed activity that leads to diverse forms of learning. These diverse forms of learning are reflected in expressions of identity, how individuals express independence and creativity, and those individuals' ability to learn, exercise judgment, and think systematically.

The defining frame for this series is not a particular theoretical or disciplinary approach, nor is it a fixed set of topics. Rather, the series revolves around a constellation of topics investigated from multiple disciplinary and practical frames. The series as a whole looks at the relation between youth, learning, and digital media, but each contribution might deal with only a subset of this constellation. Erecting strict topical boundaries would exclude some of the most important work in the field. For example, restricting the

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content of the series only to people of a certain age would mean artificially reifying an age boundary when the phenomenon demands otherwise. This would become especially problematic with new forms of online participation where one crucial outcome is the mixing of participants of different ages. The same goes for digital media, which are increasingly inseparable from analog and earlier media forms.

The series responds to certain changes in our media ecology that have important implications for learning. Specifically, these changes involve new forms of media *literacy* and developments in the modes of media *participation*. Digital media are part of a convergence between interactive media (most notably gaming), online networks, and existing media forms. Navigating this media ecology involves a palette of literacies that are being defined through practice yet require more scholarly scrutiny before they can be fully incorporated pervasively into educational initiatives. Media literacy involves not only ways of understanding, interpreting, and critiquing media but also the means for creative and social expression, online search and navigation, and a host of new technical skills. The potential gap in literacies and participation skills creates new challenges for educators who struggle to bridge media engagement inside and outside the classroom.

The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning, published by the MIT Press, aims to close these gaps, and provide innovative ways of thinking about and using new forms of knowledge production, communication, and creative expression.

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Foreword

Colleen Macklin

Do you remember when night fell and the monsters got you? Or that time you lost one of your lives? How about when your little sister died of dysentery? These are some of our fondest collective childhood memories. Games do that. The paradox of games is that they turn what is typically considered a painful circumstance into pleasure. They make failure fun.

Do you remember getting called on when you were daydreaming? Failing that important test? Getting sent to the principal's office? These are some of our least fond collective childhood memories. School isn't usually associated with fun and games—in fact, even when games are involved, one of the most vividly painful memories from school is being the last person picked for the dodgeball team (unfortunately I speak from experience). The paradox of school is that it has a knack for making the pleasure of learning painful, making failure … not fun.

Of course, not all our learning experiences in school are painful, and not all our game-playing experiences are pleasurable. But failure in a game encourages us to try again and ultimately learn new strategies. Video games in particular rely on failure to teach us how the game world works—no wonder we have multiple lives and save points. Failure is essential in video games, but failure in school is usually something to avoid. Rather than teach us how things work, failure often teaches us what we haven't learned—and on that big test, we don't get a chance to restart the level and try again. As an educator and game designer straddling both worlds, I'd rather adopt the forgiving measurement of success that Samuel Beckett proposes: "Ever tried. Ever failed. No matter. Try again. Fail again. Fail better."[1]

When we play, we're open to failure—we're trying something out. If it doesn't work the way we thought it would, that's ok, we'll try something else—we'll "fail better." We're hardwired to learn through play, but

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we don't need to turn learning into a game for it to be fun. As the authors of this book point out, learning is *already* fun. The challenge in education is to "find the fun" in a subject—not to try to "make it fun." Because the whole reason we even have math, physics, philosophy, history, mortuary sciences, and more is because someone, somewhere, at some point in time, found it fun.

"Find the fun" is a phrase I borrow from Sid Meier, the game designer for *Civilization*. He and his team found the fun—they just happened to find it in world history.[2] While educators might try to find the fun in a subject to make it more meaningful to students, for game designers, it's a matter of a game's life or death. That's where the work of the Education Arcade comes in. They are super-double fun finders. They find the fun in an educational topic—the fun that's already there—and translate that fun into a game, finding the fun again through play. This is resonant game design—the vibration between topics, systems, problems, and players who become learners. Sound easy? I can say from experience that it's not.

To illustrate why, I'd like to ask you to join me in traveling back to 2010. Notice that elephant in the conference room at Parsons School of Design, where I teach? None of the playtesters sitting around the table really wanted to say it, but the game they'd just played was … not fun.

Well, this was embarrassing.

I was the director of a new research lab (PETLab), and our latest endeavor was an alternate reality game set in 1600s Manhattan. To play, you walked around the city with your phone—a portal to early Manhattan—collecting the flora and fauna that used to be there before it was taken over by taxicabs and tourists. The project was based on years of research done by passionate scientists. The game had a talented design team and was using some really cool technology. But despite all that, the proof was in the playtest: the game just wasn't fun.

I won't go into all the reasons, but suffice it to say we got distracted by the technology and the details of the data we were using in the game. We forgot to translate into the game the fun that the scientists had experienced discovering Manhattan's early ecology. My background is in art and design, so I was no stranger to a bad critique. My colleague Eric Zimmerman says that learning to take negative feedback is like developing a taste for spicy food. I had developed the taste for spicy criticism over many years of presenting creative work. But this critique was particularly hard to swallow because

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PETLab was the new kid on the block and we were hoping to impress the playtesters we had gathered: respected designers and researchers in the field of games and learning. Some of them I was meeting for the first time, like Eric Klopfer and Louisa Rosenheck, two of this book's authors. If you had told me then that I would be given the opportunity to write this foreword, I would have stared at you, blinking incredulously.

That was almost ten years ago. The field was fledgling, and to fail was not unusual—in fact, looking back on this time, it was part of the fun. Failure drove educational game makers to make sense of what works by also sharing with each other what doesn't work, and why. Because to make something new, to bridge disciplines, and to find the fun in both involves plenty of failure at first. As the years progressed, we learned lessons together, sharing stories of our failures (and at times, successes) at conferences and in books.[3]

The team at the Education Arcade has been designing truly fun learning games for many years now, and what you'll find in the pages that follow draws from real hands-on experiences working with designers, educators, and learners. The principles of resonant games bring the best of games and learning together through real examples and true stories—forged through failure and out to the other side, success—so that you can build on them. And find your own unique ways to fail in your forays in games and learning. And hopefully, someday, succeed. Or shall we say, "fail better"?

Notes

1. From *Worstward Ho* (p. 7), by S. Beckett, 1983, New York: Grove Press.

2. Even though *Civilization* was not designed to be an educational game, it has been known to spark interest in world history, and now development of an educational edition, *CivilizationEDU*, is under way.

3. Two years after this failed playtest, Eric Klopfer and Jason Haas cowrote *The More We Know: NBC News, Educational Innovation, and Learning from Failure*. It's a refreshing and humbling story of failure told through a real example—and the lessons to be learned from it.

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1 Our Game Could Be Your Life

If you want to build a ship, don't drum up people to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea.

—Antoine de Saint-Exupéry

We are a group of scholars and game designers at the Education Arcade at MIT, where we develop learning games about scientific and mathematical concepts and real-world problems. Our goal with our learning games is to command your attention and passion and, we hope, change how you think about the world in the process. Learning is cultural, an activity that is shared and happens in communities, but learning is driven as much by passion, personal interest, and curiosity as it is by the world around you. Games are also cultural artifacts—they have bedrock roles in human culture, whether they exist as an abstract set of rules in the shared minds and memories of a community or as a box containing a mess of code on a disc that costs $60 (experience may change in online play). Games depend on shared, playful participation within a set of rules. They can bring people together and accumulate meanings within the culture at large, and they can also create particular meanings to every person who comes into contact with them. Although games are necessarily limited by a circumscribed set of rules, this capacity for larger shared meaning—resonance—makes them powerful platforms for learning.

Too often in contemporary society, though, the ideas of "learning" or "education," important mechanisms by which we induct young people into our society and provide access to all that we know and how we came to know it, are confused with "schooling." While schools are, in many societies, important locations for the enculturation of our young people, they

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can be caught up in efficiently completing bureaucratic processes or satisfying benchmarks created more for political expediency than for pedagogically sound reasons. Although game-based learning is gaining recognition within education systems, too often the games are narrowly focused on specific learning outcomes dictated by school curricula. These narrowly targeted games can fail to connect with young learners.

In the Education Arcade, we have spent over a decade designing learning games that could come to be your life—artifacts that could be a part of your life in school and at home, that could rouse your curiosity and determination, that might even seep into your dreams and imaginations. (Everyone's had a *Tetris* dream or a *Rock Band* dream, right? We talk to teachers all the time who have complex systems-simulation dreams after using our *StarLogo Nova* application.) Our games are designed to resonate with your life, with your passions, and with all the systems in which they are embedded. This book is a compendium of principles we have used to design our learning games, illustrated by projects we have created with these principles in mind. We call the sum of these principles "resonant design," and the games that embody the spirit described by these principles, "resonant games." Through this resonance, the games amplify the systems to which they are connected—school, home, life, friendships—connecting them and making them more meaningful. This is obviously not the only approach to developing learning games. We hope that by elucidating our principles and practices (and our successes and failures), we can further a culture of passionate learning with aesthetically beautiful and intriguing artifacts. We hope that we see more and more games in the world that we wish we had made!

We've seen these principles emerge in our own work over the last two decades, but we are also indebted to the great writing of James Paul Gee, Kurt Squire, Constance Steinkuehler, Ian Bogost, T. L. Taylor, Bernie DeKoven, Sasha Barab, and others who have described the value of video games (and other games) as sites of struggle, persistence, failure, great imagination, and deep learning. In other words, games are sites of great humanity, and they are frequently sites of great learning as a result. Video games are cultural artifacts and designed experiences. Games are highly effective abstractions and models for experiential learning, as well as being deeply social. They are both powerful and intimate. They are a mess. Or a mangle. Or an assemblage. They are action and reflection. We think of our games

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not as interventions that can be doled out in reliable doses with predictable results, but instead as provocations, designed to solicit questions, arouse passions, and stimulate great discussion in learning communities.

In this book we argue for a philosophy of learning game design that is passionate, highly engaged, and welcoming. We are also primarily directing our attention at the learning of young people in and around the deliberate learning environment that is American public schooling, an environment that, on average, could probably use more passion, engagement, and welcoming. One of our most adamant beliefs is that context matters, and that all educational technology is only as useful and good as its implementation. When you read this book, if you are a mentor in another sort of learning environment or you design for one, feel free to adapt our thinking to your needs—you know your context better than we will. We do take some trips outside school in this volume, so perhaps you will also find something for your situation there. In the main, though, this is a book about the roughly fifty million children who go to school every day and are faced with uninspiring learning environments—learning environments where often heroic (but sometimes not) teachers are overworked and overly constrained by (possibly) well-meaning bureaucrats who have drained schools of professional control and personal efficacy through (yet more possibly) well-meaning policies.

The Principles

While resonant games vary widely in format and content, they share characteristics that create deep learning experiences inextricably connected to the educational ecosystem they exist in. This book describes twenty design principles that we believe are essential for reaching the learners you wish to reach, getting and holding their attention, and even invading their dreams. We have distributed the principles throughout the book organically, tying these broad, abstract ideas to appropriate projects from our lab that we believe illuminate and exemplify them. Instead of debuting all twenty principles here in the first chapter and risking overload, we instead present four broad overarching organizing principles for how we see resonant design.

First, honor the whole learner. Resonant design is incompatible with views of learning and of intelligence that see those seeking to learn as

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empty vessels awaiting "fill-ups" on knowledge. Learners must be seen as full human beings with a range of passions, likes, and dislikes. They have homes, social lives, and interests outside a given opportunity to learn. They have good days and bad days and physical bodies. We believe that we as game makers must hook students using all the things that hook us (and probably hook you too): telling them a good story; trying to understand them well enough to present them with puzzles, challenges, or other provocations that speak to them; and meeting them where they are. Human beings may be at their best when they are imagining how things might be otherwise, or when they are hard pressed to solve a complex problem, or maybe both. The best games for learning, we feel, place the learner in situations that might strike their fancy as well as presenting problems that keep them up at night. It helps to know and like people, and to know what people are like, too. Learners do not come in standard packages, and individual lives, tastes, and minds are highly idiosyncratic. Accordingly, we know that not every problem is going to enthrall everyone alike.

Second, honor the sociality of learning and play. Very few of the games described in this project are what might be called "single-player" games. Most of them could probably be played (or even have phases that should be played) in an isolated, "just me and my computer" fashion, but those players would be missing out on essential parts of the experience. Resonant design is predicated on the idea that learning is both an individual and a social experience. Self-taught learners who never connect their knowledge to that of others may have reliable abilities to produce meaning, but those meanings may lack validity. Resonant games are designed so that they bring many players into conversation with each other and with the game, drawing people into the world together through provocation instead of by broadcasting a single message. It is important to provide several challenges for players to do together, to figure out together, and to reflect on together. Providing players with open-ended, ill-structured problems can greatly aid this, as can putting players into situations of collaboration, cooperation, and even competition. Growing evidence and theory points to the tremendous importance of sociality to humans, and as such, it is a crucial piece of resonant design.

Third, honor a deep connection between the content and the game. Resonant design takes the connection between learners and knowledge, skills, and practices very seriously. All games, in their way, are learning

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games—players learn systems, strategies, and tactics; they learn about their opponents and teammates—but the games we are discussing are those specifically for learning what some may call "academic" content and skills. We are circumspect about the use of this word only because many of the ideas, skills, stories, and habits that could be considered dry or overly abstract are actually pretty wonderful. Some are useful; some are inspiring, giving us a sense of the world beyond our experience; some help explain how and why the world is as we encounter it; and some challenge our understanding of the world. Most have some connection to people's everyday reasoning. We sometimes hear designers, publishers, and funders say things like, "Can you make [a certain topic] fun?" This seems like a mistake to us, because most human knowledge was pretty fun for *someone* to create. Someone *really* wanted to understand how to balance the value of discrete unequal things, so they invented algebra. Someone *really* wanted to understand the causes of systemic racism in America despite the unrelenting bleakness of the subject matter, and researching it was *fun* for them. To help students develop competencies and develop their own passionate questions about the world, it is essential to figure out what is already fun about the matter at hand. The thing you want your students or audience to know is already fun. If you are asking, "How do I make [this topic] fun?" then you need to reconsider your approach. Resonant design is not about inserting content into games. It is about deeply connecting the game and the learning. It is not about fun in the sense of continuous enjoyment, but rather fun in the sense of continuous engagement. This is why we chose the Saint-Exupéry quotation as an epigraph for this chapter, as well as the *xkcd* webcomic below (figure 1.1). In the comic, beloved, exemplary scientist Richard Feynman has returned from the dead to make it clear to someone abusing the giddy research energy of TV's *Mythbusters* that her wan professionalism is as far from the core of science as Pluto is from the sun (or from being a planet).

Fourth, honor the learning context. While learning does happen all the time, all over the place, most academic knowledge is learned in schools. For the vast majority of American students, including those hardest to reach and those with the least opportunity to access complex academic ideas, this means the public school system. While some consider this situation a massive tragedy, and others, a great benefit, to us, it simply is. This is the context in which we design. Resonant design is dedicated to finding

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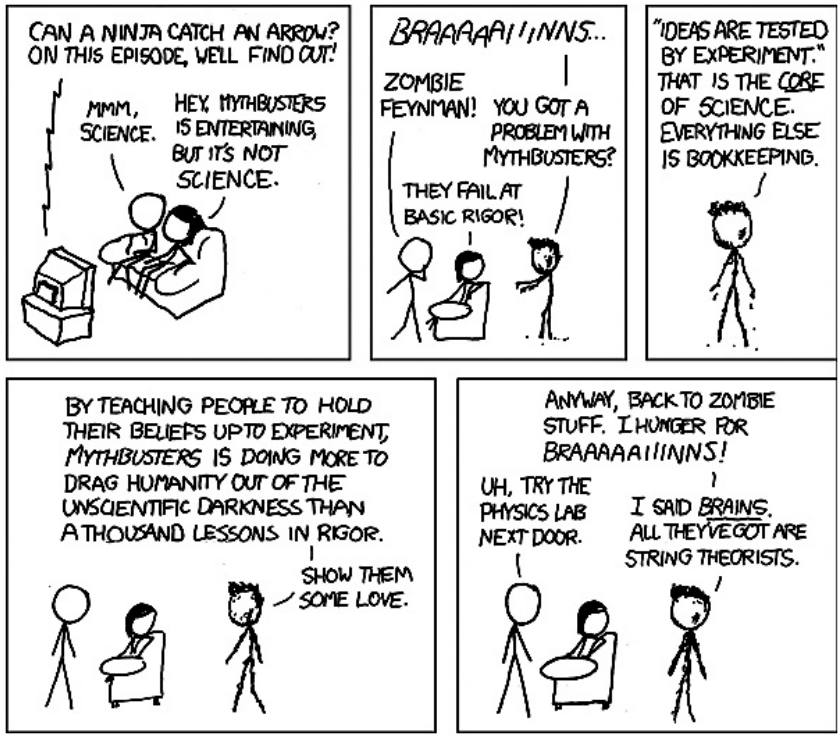
CAN A NINJA CATCH AN ARROW? ON THIS EPISODE, WE'LL FIND OUT!
MMM, SCIENCE.
HEY, MYTHBUSTERS IS ENTERTAINING, BUT IT'S NOT SCIENCE.
BRAAAAAI!!NNS...
ZOMBIE FEYNMAN!
YOU GOT A PROBLEM WITH MYTHBUSTERS?
THEY FAIL AT BASIC RIGOR!
"IDEAS ARE TESTED BY EXPERIMENT." THAT IS THE CORE OF SCIENCE. EVERYTHING ELSE IS BOOKKEEPING.
BY TEACHING PEOPLE TO HOLD THEIR BELIEFS UP TO EXPERIMENT, MYTHBUSTERS IS DOING MORE TO DRAG HUMANITY OUT OF THE UNSCIENTIFIC DARKNESS THAN A THOUSAND LESSONS IN RIGOR.
SHOW THEM SOME LOVE.
ANYWAY, BACK TO ZOMBIE STUFF. I HUNGER FOR BRAAAAAI!!NNS!
UH, TRY THE PHYSICS LAB NEXT DOOR.
I SAID BRAINS. ALL THEY'VE GOT ARE STRING THEORISTS.

Figure 1.1
"Unscientific," from *xkcd*, by Randall Munroe, https://xkcd.com/397/

the patterns necessary for fitting designed experiences into people's lives and into contemporary classrooms. It is also dedicated to finding the best ways to work with educators and policy environments to ensure that complicated educational experiences can be used in the classroom and will be used in the classroom. This means codesigning experiences with educators, developing bridge curricula, paying careful attention to standards and other policy variables, and providing professional development for educators. We are still dedicated to a progressive pedagogy that aims to change many of the ways in which public education is approached. A crucial part of our practice involves compromising on issues that do not matter in order to ensure adoption, while fiercely maintaining the integrity of our pedagogical philosophy and learning goals.

We also recognize that while school is the principal site of learning in our society, our cultures of learning can be somewhat impoverished outside

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schools. Resonant design is as dedicated to fitting into lives outside school as it is to fitting into school. Resonant games are devoted to the ideas of lifelong learning and access to knowledge and skills in modalities beyond the classroom.

The design principles in these four broad categories have emerged as the characteristics that best describe resonant games and represent their commonalities. Any one game need not embody all twenty of the principles to be considered a resonant game, but it should incorporate many of these ideas. Each principle is discussed in depth in relation to the project where it can be seen most clearly, but each one naturally applies to a variety of projects, and those common threads are woven throughout the chapters of the book. The principles are not designed to be a checklist or evenly applied to all games. Depending on the situation, context, domain, game style, and other factors, some principles are more critical and are adhered to more strictly than others. Designers need to determine how these factors vary; we discuss how to do so throughout this book.

The Games

Beginning in chapter 3, we explore our specific design principles—principles connected to the four described above—in connection to five games or collections of games we developed in our research group at MIT, the Education Arcade. Each of these games has a different story of how we were inspired to develop it and how we came to fund it, design it, and distribute it. Along the way, we learned a great deal about our development process and how to adhere to our principles. Indeed, the principles themselves may have even been distantly fuzzy when we started working on these games, but they appeared more crisply the closer we sailed. Some principles still remain fuzzy or elusive, and we cannot wait to see what the audience for this book does with them. Here are some brief descriptions of our games:

Lure of the Labyrinth (figure 1.2) is an online game that uses a compelling graphic novel storyline to engage middle school students in mathematical thinking and problem solving. In this browser-based game, players control a character walking around a labyrinthine world, in which they must retrieve a lost pet from underground monsters by overcoming obstacles in the form of mathematical puzzles. The mathematics is designed for middle school pre-algebra students, and is aligned with both Common Core

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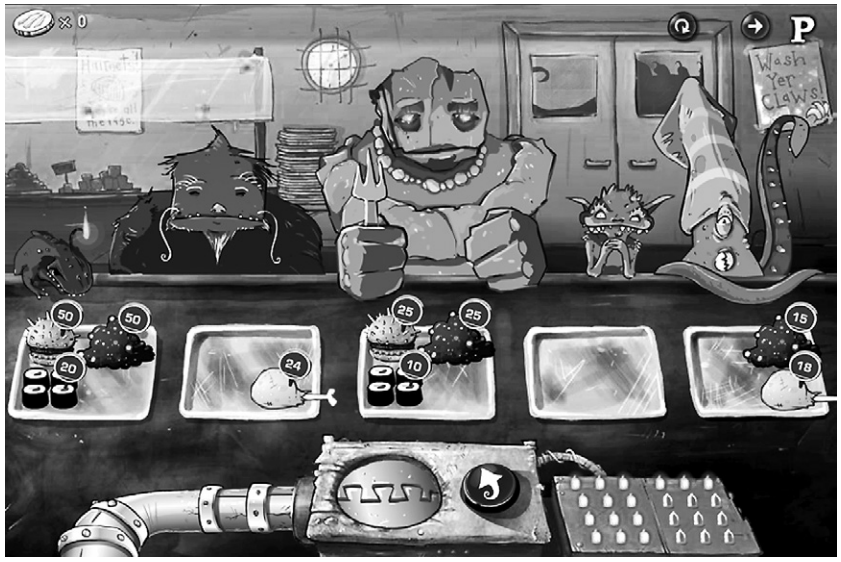

Figure 1.2
One of the puzzles from *Lure of the Labyrinth*, in which players must appease the monsters with the correct delicacies using ratios and proportions to determine the right sizes

and NCTM standards (i.e., National Council of Teachers of Mathematics). Teachers are able to create groups of students, monitor their progress, and connect the game tasks directly to mathematics concepts in their classes. *Labyrinth* was funded by the US Department of Education, through funding to Maryland Public Television. We designed at MIT, and Fablevision produced it. To date, students have used math and problem-solving skills to save more than 30 million pets!

Labyrinth illustrates the following principles:

- Cultivating player identity
- Scaling across time, space, and users
- Preparing for future learning
- Deepening complexity
- Guiding reflection

Vanished (figure 1.3) was a curated alternate reality game exposing middle school students to careers in STEM by engaging them in the work of scientists. The main structure for the game was a narrative about the discovery of an earthlike planet devoid of life. The players got brought into

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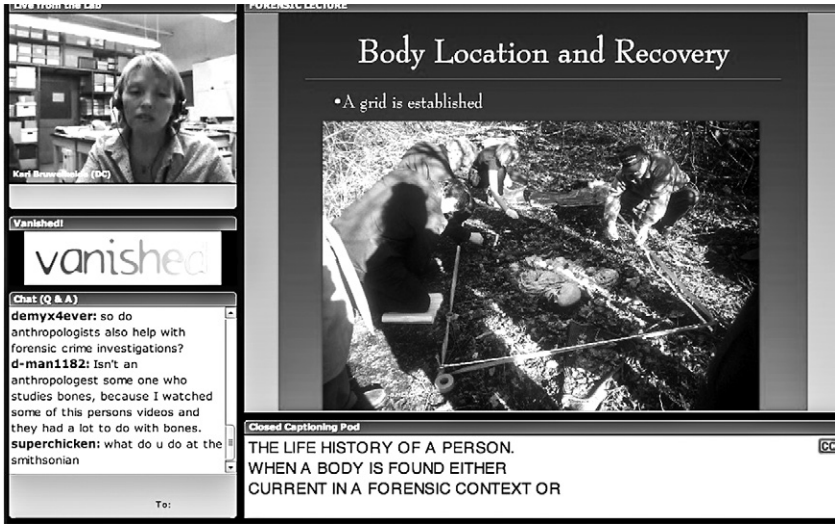
Vanished!
vanished
Chat (Q & A)
demyx4ever: so do anthropologists also help with forensic crime investigations?
d-man1182: Isn't an anthropologest some one who studies bones, because I watched some of this persons videos and they had a lot to do with bones.
superchicken: what do u do at the smithsonian
To:
Body Location and Recovery
•A grid is established
Closed Captioning Pod
THE LIFE HISTORY OF A PERSON.
WHEN A BODY IS FOUND EITHER
CURRENT IN A FORENSIC CONTEXT OR

Figure 1.3
One of the live interviews and conversations with Smithsonian scientists that is part of *Vanished*

the story and were recruited to collectively figure out what had gone wrong on that planet. As an alternate reality game, *Vanished* integrated online minigames, visits to museums, and interaction with real-world places and objects as players solved a series of puzzles. Players collaborated online and in person. They also received help from MIT student facilitators and Smithsonian scientists to solve the mystery. Some of the academic areas this pursuit was related to were life sciences, environmental sciences, paleontology, archaeology, geology, anthropology, math, the arts, and language arts. *Vanished* was funded through the Informal Science Education division of the National Science Foundation. The main target was to directly reach students online, which we did through a partnership with the Smithsonian museums and their network of affiliates. But then several clubs formed independently in schools and in other centers that organized students working on the weekly challenges. *Vanished* was a one-time event that reached more than six thousand middle school students across its nearly two-month long run.

Vanished illustrates the following principles:

- Providing multiple pathways
- Constructing knowledge socially

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- Creating a strong narrative
- Providing authentic contexts
- Making space for imagination

The Radix Endeavor (figure 1.4) is a web-based massively multiplayer online role-playing game set in an earthlike world in a Renaissance-like era. Players take on the role of a character in an underground society trying to use math and science to improve the world. In this world, students can simulate how a particular species might adapt to environmental changes over many generations. By examining virtual animal droppings, students can diagram the connections between plant and animal species in a virtual ecosystem. The game covers topics in introductory high school biology and tenth-grade math (geometry, statistics, probability), which are aligned with Common Core and the Next Generation Science Standards. *Radix* is designed to be integrated directly with classroom instruction on the related topics. Ideally, students complete quests on a topic for homework, which the teacher can connect to core classroom learning through bridging curriculum provided to teachers through the game. So far, *Radix* has reached

Figure 1.4
A player in *Radix* speaking to a merchant NPC (non-player character) to work on an algebra quest

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around twenty thousand users. It was funded by the Bill and Melinda Gates Foundation and developed in partnership with Filament Games.

Radix illustrates the following principles:

- Designing systems for exploration
- Working within an educational system
- Providing professional development
- Making curricular connections
- Creating a culture of inquiry

Ubiquitous Bio (figure 1.5) is a series of casual mobile games designed to promote deep learning and strong engagement for high school biology students in the areas of genetics, protein synthesis, evolution, and food webs. These games are designed to be played on smartphones in short stints throughout the day: while waiting for the bus, between classes, and so forth. The games are easily accessible and allow the players a low barrier to entry, with opportunities to level up to more difficult concepts as well as revisit concepts over time. For example, in *Beetle Breeders*, the players run a pet shop specializing in exotic beetles, which they must breed with

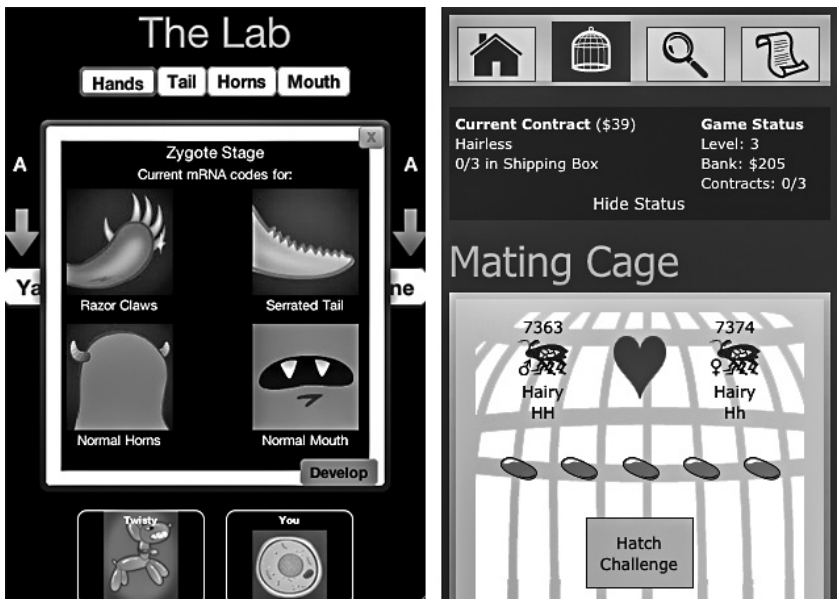

Figure 1.5
The Ubiquitous Games *Invasion of the Beasties* (left) and *Beetle Breeders* (right)

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a knowledge of Mendelian genetics. The content was designed for high school introductory biology classes and is aligned with Massachusetts state standards. Teachers deploy the games, which students access through borrowed smartphones. The teachers in turn get access to student data on performance as well as curriculum to bridge game content with class content. The series of games was developed entirely at MIT with a grant from the National Institutes of Health.

UbiqBio illustrates the following principles:

- Integrating into everyday life
- Connecting data to practice
- Designing adaptive experiences
- Codesigning with educators

Farm Blitz (figure 1.6) and *Bite Club* are a pair of online browser-based and mobile games that address financial literacy. While the content is accessible to a fairly broad audience, the goal is to focus on recently financially vulnerable young adults. Each game focuses on a core challenge for this audience. *Farm Blitz*, a game in which you run a farm with rapidly proliferating

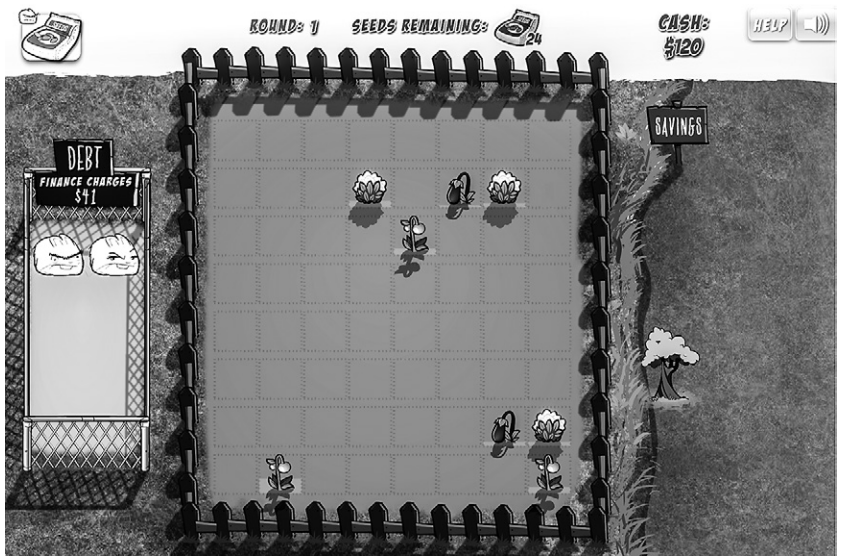

Figure 1.6
A small farm in the game *Farm Blitz* showing the rabbits (as a metaphor for accumulated debt) and the food remaining in the garden (© 2017 Commonwealth)

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rabbits, is about interest rates and the challenges of compounding interest on debt. *Bite Club* is a game in which the player runs a nightclub for vampires. Through this experience, players wrestle with challenges around accumulating debt and paying current expenses. Both games were designed by people within the Education Arcade, developed by Fablevision, in partnership with Commonwealth, a nonprofit focused on financial literacy. They were also distributed through a partnership with Staples. The games have been played hundreds of thousands of times and were featured prominently in the press.

Farm Blitz and *Bite Club* illustrate the following principles:

- Working with the right partners
- Facilitating lifelong learning
- Fostering communities of practice
- Applying skills to daily life

Before we delve into these in-depth examples, we want to reiterate that this is a practical book. Our practices draw on a great deal of important theoretical work by others, as we describe in the next chapter, but the principles of resonant games arose from our own deep and detailed engagement with specific games and contexts. In trying to codify resonant design, we are seeking only to start a conversation connected to a common set of values that we believe may help designers, developers, practitioners, and others access some criteria for what a truly great learning game might look like. We are definitely not insisting that resonant games are the One True Tool for a progressive education. We view these games as a series of interesting objects that could be considered highly desirable components of any student's or community's educational ecosystem. If we achieve what we hope, then our games may inspire others to adopt these ideas as an approach. We hope that this book is as fun and exciting for you to read as it was for us to develop.

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2 Resonant Learning

In defining resonant design, we want to be clear about how we think about games, play, and learning, as well as playing in schools. Our practice as designers draws on a large body of work in a rich variety of disciplines. In this chapter, we briefly explain our orientation to the larger body of literature. For those looking for a deeper dive, we highly recommend the work of the people we mention below. Here, our focus is on simply introducing some of the ideas that we have found valuable. These ideas inform our games and principles as part of the process of design-based research, through iteration, tradeoffs, and creativity.

Learning

Much of our intellectual foundation in learning stems from learning sciences research, which positions learning at the core of all human endeavor. Most of the things people do in their everyday lives—speaking, tying shoes, using the handle of a door, driving—are learned, and we are all likely learning something new every day (Bransford et al., 2000). The learning sciences seek not only to understand how we learn but also to improve instruction. There are better and worse opportunities and situations for learning, and by recognizing this, we can advocate for certain types of learning experiences over others.

We can define learning as the process of moving from a novice perspective to an expert's skill or to knowledge. Some of the most important strategies to help a learner move from novice to expert understanding are scaffolding, metacognition, and attention to conceptual change.

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• Scaffolding means instructors assist students in understanding by using structured supports that can fall away as students develop their abilities. For example, coaster bikes allow children to learn to ride a bicycle by helping them develop balance before skills in pedaling.
• Metacognition involves helping learners be aware of their own thinking and learning, which helps them take command of and responsibility for their own education. Understanding what one knows and what one still wishes to know can help learners passionately pursue their interests.
• Conceptual change refers to the important moment when a learner's conceptual model of a phenomenon in the world transitions from an incomplete or incorrect one into an accurate one.

Creators of good learning games will pay close attention to these concepts in their designs.

An idea central to our development of resonant games is that learners will best develop knowledge and skills by doing things in the world—knowledge is not delivered but constructed by the learner through and during activity and discovery. The educator and philosopher John Dewey developed this idea at his Laboratory School at the University of Chicago, and Dewey's ideas have influenced many other models of experiential learning. We highlight a few essential ideas and paradigms here—if you are curious, we hope you will track down more of this work, as it is tremendously inspiring.

• From problem-based learning and inquiry learning (cf. Hmelo-Silver, 2004; Holbrook & Kolodner, 2000), we take the idea that questions are crucial to education. By focusing on problems or challenges, learners face questions from others as well as their own questions, creating a clear frame within which to work.
• In project-based learning (Blumenfeld et al., 1991) students learn skills and knowledge and are encouraged to follow their curiosity in carefully scaffolded projects, like starting a small business or building a new park. The learning and creativity in response to challenging real-world constraints is extremely inspiring to us.
• Seymour Papert's model of constructionism (Papert, 1993) emphasizes the creativity of the learner. Papert extended Piaget's notion of children as active agents in building knowledge structures by observing that this happens best when they are engaged in creative, hands-on activities.

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Resonant games are also designed for learning with others. Paradigms like cognitive apprenticeship, communities of practice, and communities of learners emphasize not only learning by doing, but by doing things together with others, often in carefully designed activities that balance the agency and self-direction of learners with an egalitarian spirit that encourages all to learn and to learn together.

Resonant games are indebted to a great deal of work on sociocultural learning theory, particularly the importance of context and situation to learning (Lave & Wenger, 1991) as well as the critical value of coaching, modeling, and supporting by thoughtful mentors (Brown et al., 1989; Rogoff, 1994) as well as by other members of the community (Wenger, 1998). Roles, shared goals (Brown, 1997; Aronson & Patnoe, 1997), and carefully designed tools for producing shared knowledge (Caswell & Bielaczyc, 2002; Roschelle, 1992) are all also essential to the development of the resonant games paradigm. Most important is the idea that resonant games *situate* the activities and knowledge in contexts that are meaningful to the learner as well as significant in the larger societal context.

The resonant games approach as an educational technology philosophy is one of transforming classroom practice, not merely digitizing existing practices. One could think of this as the difference between model United Nations innovations and classroom *Jeopardy*. While *Jeopardy* can be an undoubtedly fun way to drill on facts, it provides what gamers might call a weak reskin of the traditional initiation-response-evaluation classroom dynamic (Polman and Pea, 2001). This ping-pong dynamic between students and teachers is anemic in the face of the wild questions, problems, and opportunities for learning that occur in a rich, structured-but-multilateral activity like model UN. Resonant games are for use in a learning environment in which student questions and interests are an important part of the educational exchange. We believe that resonant games, through ambiguity and aesthetic interest, create experiences and opportunities for just this sort of exchange.

Criticisms of these approaches sometimes lump these types of learning theories under the broad category of "discovery" learning, arguing primarily that these experiences are so rich and complex that facts and skills might not stick in learners' memories (Kirschner et al., 2006). To this end, resonant games must be experiences worth talking about, allowing novices to develop the questions that will lead them to expertise. Joplin's (1981) work

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in experiential learning is a useful model for how to help learners attend to important information and contextualize it usefully.

In this model, students are focused on skills and information before a challenging activity like a learning game, and they debrief the experience afterward as a community of learners, with mentors giving feedback and support along the way (figure 2.1). Although resonant games provide some kinds of technological feedback and support to players in a game, we design the games to, as much as practical, engage players with human supports, including teachers, parents, and peers.

As we discuss in detail later, resonant games are usually designed as *preparation for future learning*. The result of addressing a challenging action in an experiential learning context and the subsequent debrief will not always result in formal analytical knowledge. Coming out of the debrief, however, students may have material understanding of, for example, pre-algebra *concepts* as well as their own questions and ideas of how to solve such problems. As John Bransford and his colleagues state, "There are times, usually after people have first grappled with issues on their own, that 'teaching by telling' can work extremely well (e.g., Schwartz and Bransford, 1998). However, teachers still need to pay attention to students' interpretations and provide guidance when necessary" (2000, p. 11). This is an approach frequently used with science center field trips. Perhaps the best example of games as preparation for future learning is a study in which community college students, in preparation for a lecture on World War II, were randomly assigned to one of three groups. One control group, one group that played a squad first-person shooting game, and one that played *Civilization*.

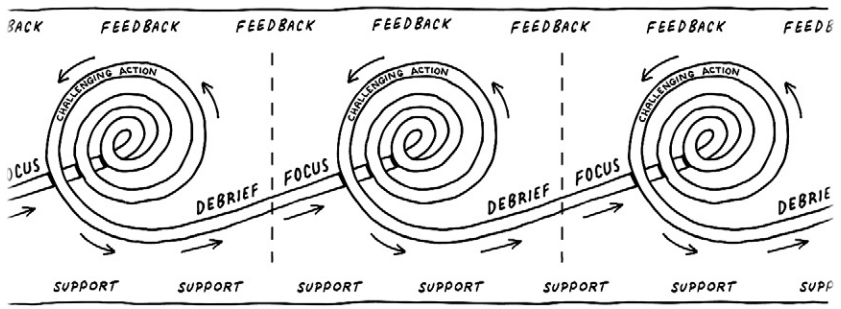

Figure 2.1
A diagram of experiential learning (adapted from Joplin, 1981)

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The game players did better on a postlecture exam than the control group, and the first-person group focused more on tactics on the ground, while the *Civilization* players focused more on global issues (Arena, 2012).

Play

Play and Fun

Lev Vygotsky wrote, "A child's greatest achievements are possible in play, achievements that tomorrow will become her basic level of real action" (1978, p. 100). In other words, the imaginings and investigations that children perform in the guise of what we call play are the essential materials and resources of child development. Play is often equated with fun. Ian Bogost (2016) writes that "play is carefully and deliberately working with the materials one finds in a situation" (p. 113), and fun is "not the effect of enjoyment released by a system, but a nickname for the feeling of operating it" (p. 114). As we shared in chapter 1, we often hear the idea that playful learning activities should "make learning fun," as in, "make math fun." But these topics and situations are already fun and interesting at some level or to some people, and students often need only an appropriate lens to the right kind of problem. The idea of making learning fun positions learning environments and experiences on a single axis, between "play" and "learning," with a move in either direction on the axis necessarily sacrificing the other value (see figure 2.2). Any movement toward playfulness necessarily means a less useful learning experience, and vice versa. In other words, you can give up play to have more learning, or give up learning to have more play.

In the Education Arcade, we prefer to think of play and learning as a plane with "play" and "learning" as perpendicular axes (see figure 2.3). Learning is often a playful experience, and the activity of playing often

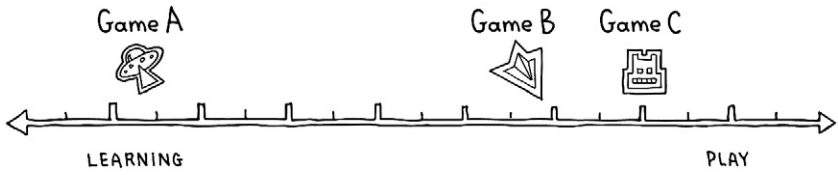

Figure 2.2
The play/learning axis

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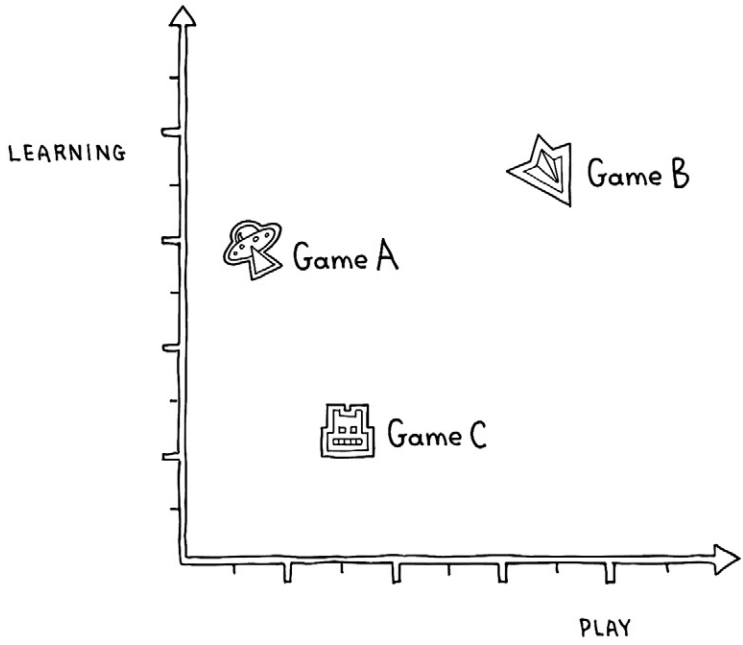

Figure 2.3
The play/learning plane, where Game B is the goal, maximizing both learning and play

involves learning. Most importantly, in any given experience, learning and play are positioned in a zero-sum struggle. Resonant game design purports that experiences can often be their best when both play and learning are maximized in the design and execution of the plan.

Play and learning scholars have often discussed the concept of flow—"optimal experience" moments of playing, in which extreme skiers, mountain climbers, and *World of Warcraft* raiders find themselves in a perfect channel of experience, free from boredom on one hand and anxiety on the other (Csiksentmihalyi, 2000). We rarely aim at "flow" in designing resonant games. There is evidence that games whose mechanics specifically drive toward flow and optimal experience are usually designed for individual experience and can in fact impede learning, while playing with others is more effective for learning and reflection (Raphael et al., 2012).

What can be fun, however, is for learners to have experiences within their zone of proximal development (ZPD). The ZPD is the zone in which

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children can advance a skill or accomplish a task with some help (Vygotsky, 1978). Children learn by staying in the ZPD as long as possible, working at the edge of their competence. This leads us more often to think in terms of the engaged attention that Seymour Papert called "hard fun."

In an essay, Papert (2002) says hard fun

> is expressed in many different ways, all of which all boil down to the conclusion that everyone likes hard challenging things to do. But they have to be the right things matched to the individual and to the culture of the times. These rapidly changing times challenge educators to find areas of work that are hard in the right way: they must connect with the kids and also with the areas of knowledge, skills and (don't let us forget) ethic adults will need for the future world.

An appropriate problem that is hard fun (in this case, building a robot)

> requires concentration and discipline. It requires learning to deal with things going wrong by finding out how to fix the problem rather than by giving up in frustration. And for some of those kids it has meant experiencing for the first time the pleasure of writing because they were encouraged to write about something they were doing themselves and doing with passion. (Papert, 2002)

Play and Freedom

Our own Scot Osterweil has advanced four *freedoms* of play, which illuminate the kinds of things we can do while playing—the kinds opportunities that working a problem playfully can afford us. These freedoms should be carefully considered when developing learning experiences, as institutions like schools, even very progressive ones, can strip learning experiences of freedom.

Osterweil's four freedoms of play:

- Freedom to explore: Play allows for players to fool around, to investigate, to run their minds over the surfaces of a new problem or idea, to be surprised by some new idea or experience. You might think of idly putting together Legos or playing with wooden blocks and stumbling on mathematical concepts or equivalence, as Papert famously did, or learning deeply about ratio by fiddling with the gear box of an automobile (see *Mindstorms: Children, Computers, and Powerful Ideas*, 1980).
- Freedom to fail: Play is an excellent opportunity to discover one's capacities as well as the possibilities of materials, systems, and other learning objects without fear of reprisal and with minimal impact on one's sense of competence. James Paul Gee refers to this as a "psychosocial moratorium" (2003).

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• Freedom of identity: The capacity to investigate your own identity by trying on other identities and learning what it feels like to perform different types of actions and to ask all sorts of questions.
• Freedom of effort: Play is healthily anchored in a freedom to exert oneself maximally, but also to maintain a lusory attitude (Salen & Zimmerman, 2003) while hanging back, observing, and/or reflecting, as a child playing tag may cease to run hard and instead watch from the periphery before reentering the fray (Opie & Opie, 1969).

Play and Self-Determination

We find the ideas of self-determination theory quite compelling to explain how to design playful and resonant activities. The theory asserts that in order for people to flourish, they need to experience competence, autonomy, and relatedness (Ryan & Deci, 2000). Sebastian Deterding (2012) claims that play is a truly remarkable state of being, free from stress and fear, in which we are able to pursue these three goals. We believe that the kind of games that allow for freedom and hard fun certainly push toward competence and autonomy. The third goal, relating through play, can be somewhat more complex.

Playing with others, interacting, cooperating, and reflecting in a learning community can be a remarkable way to meet learners' need for relatedness in learning contexts. We believe that understanding the social aspect of learning is essential for learning designers. Social play has been ubiquitous and essential to human culture for as long as it has existed. Nonetheless, designers need to be aware of the possibilities of play's darker side. Brian Sutton-Smith (1983) talks of "cruel play," in which children and adults both exalt in the domination of others, and Marjorie Harness Goodwin (2008) writes of the ways in which girls' games and play are used to exclude and diminish each other. Players may feel a real sense of shame if they fail to perform in certain contexts like public play, which contravenes a freedom to fail. Teachers and mentors using playful methods must take care to monitor how play is manifesting with their learners, and designers must pay close attention to the social affordances of their activities.

Finally, play in learning contexts should not be limited to instilling relatedness only between players. Resonant design should include teachers and other learning coaches, being careful not to "instrumentalize" play

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and games to fill time on a rainy day or to reward students for finishing a "serious" activity.

We believe that play and respect for students' sense of autonomy, competence, and relatedness should be located at the heart of all learning activities. We strive to create opportunities for curricular autonomy and recognition of professional competence for educators, *as well as* allowing students to be whoever they want while encountering opportunities to fall in love with something new.

Games

Games, for us, are vehicles for play. We principally use Bernard Suits's definition of games: the voluntary overcoming of unnecessary obstacles (Suits, 1990). Other useful features of games, like rules and goals, can be essential for playful learning, but we begin by considering the simplest definition. As Suits says, playing golf is absolutely the worst way to accomplish the goal of getting a small ball into a very small hole far away. We hit the ball with a series of sticks because it is fun, and we enjoy it (even when it is, to be polite, Papert's hard fun). Games are generators of play because they create unnecessary obstacles that we want to engage with and overcome anyway (often through goals, rules, and other structures). Resonant games should be just that, then—unnecessary obstacles that are meant to be (mostly) voluntarily engaged with for use as learning environments and in learning communities.

Games and learning scholar James Paul Gee (2008) has summarized the ways in which these constraints and structures make games, and particularly video games, excellent learning environments. Six main features of games can facilitate deep learning:

- Games use rules to achieve meaningful goals. This means players are attempting to achieve something in the game, and that the goal feels organic and personal, not generic.
- Players have the power of microcontrol. For Gee, games generally offer one of two perspectives on the world of the game: either they provide an embodied intimacy or they extend the player's reach of power and vision. These are two ways to acquaint players with the systems within one's game—either by granting them a powerful, all-seeing status in which they

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manage key parts of the world, or from an on-the-ground perspective, connecting with an avatar and that character's experiences of the systems.

• Games for deep learning feature the best of what studies in the learning sciences have been able to tell us about excellent environments for learning *from experience*. Gee highlights the value of games providing a goal, feedback in pursuit of that goal, opportunities to demonstrate and transfer the skills used in pursuit of that goal (or goals), and then the opportunity to formalize players' experiences and further develop or elaborate these skills in concert with others in discussion and collaboration.

• Games can offer concrete experiences with underlying models that enable learners to easily abstract their experiences toward more general concepts.

• These concrete experiences can allow for probing by matching the tools or bodies of players' games to the Gibsonian affordances of the world, giving meaning to their probes and their intuitions about how things might work.

• Finally, games for deep learning allow their players to create narratives about their experiences that they can share with others as part of the formalization process described above. These narratives should have trajectories that allow them to do all sorts of things, including understanding their relationship to the world and to knowledge.

Gee (2003) also pointed out that games are crucial because they connect us with knowledge, with our sense of ourselves, and with others in ways that demand not only attention but passion.

These remarkable properties position games as rational tools that modify the world and permit learning by experimentation and discovery. Kurt Squire's work builds on this, but he points out the aesthetic dimensions of games as important in making them powerful learning environments (Squire, 2002, 2006, 2011). Squire's work heavily underpins resonant design. Some aspects of games cannot be reduced to just rich intellectual experiences, but spill over into our bodies and our hearts. Squire recognizes how much gamers love their games, and the importance of this for learning. Learners almost always do better in their learning if they are deeply interested in what they are to learn, taking responsibility for their own learning. Squire recognized that emotional experiences, such as being caught up in a world, feeling like an expert and a competent actor, can be extremely important. The aspects of a game that cannot be reduced to the logical or

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the practical—the aesthetic aspects—can seduce people into caring about the modeled world and tools of the game (see also Hunicke et al., 2004). Players are more likely to try to understand the surfaces and limits of places and problems if they feel a deep connection. Resonant games aim to draw players in, absorbing them with the frames they draw around situations and with their point of view on knowledge and skills. Resonant games are designed with a passionate love for knowledge, modeling that knowledge carefully and in a manner ripe for exploration.

How is this expressed? One argument for how games might express ideas to learners is the idea of procedural rhetoric, which is "the practice of authoring arguments through processes" (Bogost, 2008, p. 125). Rather than explicitly stating a point of view, a game can convey that message through an experience. Games with explicit or "easily read" procedural rhetoric, however, are frequently not fun and generally leave no room for the player to engage meaningfully with the modeled system. Rather, procedural rhetoric usually works best when it is shaping the game without becoming the center of the experience.

This might be in part because of the value of uncertainty and ambiguity. Mastering uncertainty is central to the appeal of games (Costikyan, 2013; Koster, 2013). Similarly, ambiguity enables designers "to suggest issues and perspectives for consideration without imposing solutions. … [It] is a powerful design tool for raising topics or asking questions, while renouncing the possibility of dictating answers" (Gaver et al., 2003, p. 240).

Resonant design employs these types of tools to avoid the control and dogma that many associate with schooling and education, offering autonomy to the player instead. Piagetian scholar of teaching and learning Eleanor Duckworth has written and taught on the topic of "the having of wonderful ideas." She wrote about a Piagetian interview she conducted with a seven-year-old boy named Kevin who, when presented with ten drinking straws cut to different lengths, spontaneously and joyously arranged the straws by length. Other children had needed to be asked to arrange the straws, but not Kevin. She writes:

> It wasn't easy for him. He needed a good deal of trial and error as he set about developing his system. But he was so pleased with himself when he accomplished his self-set task that when I decided to offer them to him to keep (10 whole drinking straws!), he glowed with joy, showed them to one or two select friends, and stored them away with other treasures in a shoebox.

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> The having of wonderful ideas is what I consider the essence of intellectual development. And I consider it the essence of pedagogy to give Kevin the occasion to have his wonderful ideas and to let him feel good about himself for having them. … [T]he right question at the right time can move children in to peaks in their thinking that result in significant steps forward and real intellectual excitement; and … although it is impossible for an adult to know exactly the right time to ask a specific question of a specific child … children can raise the right question for themselves if the question is right. Once the right question is raised, they are moved to tax themselves to the fullest to find an answer. (Duckworth, 1996, p. 1)

Is arranging ten straws of different lengths a game? Is playing a game the essence of intellectual activity? Kevin's straws have a lot in common with a game of golf in our opinion. Any given learning activity can be more or less "game-y," referring to the intended and received effects of the activity's elements—for instance, its mechanics, dynamics, and aesthetics (see Hunicke et al., 2004). The straws pose a problem through their affordance of being uneven, but what might be done with them is up to the learner. It is ambiguous what, if anything, is the right thing to do with them, despite a procedural rhetoric that implies order (among other things). Kevin is thus presented with a problem and left alone to tinker with it and have his own idea. While basic, this is a resonant game.

We're emphasizing this because much has been made of the disservice done to games by instrumentalizing them in in teaching and learning—deploying a game as a tool. Designer and scholar Frank Lantz, during the question-and-answer section of a talk given at the 2014 Game Developer's Conference, asserted that to use a game to teach (the questioner specifically referenced *Civilization*) is like using music to help you learn the alphabet: "You can do it, but it's not the main thing we like about music." In this same talk, Lantz states that games should "make us smart, interesting people," but he does not seem to have a mechanism other than osmosis by which this happens (Lantz, 2014). We would argue that the cultural process of players apprenticing themselves to the game and *learning from it* changes them. This usually happens in a community of fellow learners.

One need only look at the work of Squire and his colleagues with and on *Civilization* to see that remarkable teaching and learning can be done with such a game, making the game better than it is in its initial life as a mere consumer product. The game affords and inspires all the marvelous work that Squire did with remedial history students for his dissertation (Squire, 2002) as well as the extensive work done in the Apolyton University

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community online (Squire, 2011). Still, we believe that the people doing the teaching and learning around the game are what make it truly great. Lantz's talk manages to emphasize games' unique position, saying that games are the aesthetic form of thinking and doing, learning for its own sake, while allowing us to contemplate these operations about our own minds, but he is unable to see the strange wonder of *Civilization* as a potential educational experience.

Note that while we may be relaxed around the word "games," we definitely did not name this section "simulations." The playfulness of Abraham Lincoln or Gandhi running civilizations for thousands of years is an aesthetic contribution to the overall experience of playing *Civilization*. Living in that world, being drawn into the puzzles of that game, does not mean you have been literally trained to rule a Stone Age civilization into its glorious empire years. It means you have developed what Andrea DiSessa (2001) (and Gee) would call a material intelligence for thinking about the development of a civilization. It means that the game's affordances allowed you to make interesting decisions that, by dint of being complicated and initially murky, drove you to consider the features and surfaces of the problem deeply. It means that you have tested and probed the world and your own mind at the same time in pursuit of victory and knowledge. If you aren't paying attention to your thinking at first, a competitive spirit may drive you to do so in the face of failure. *Civilization* may cause you to ask hard material questions that arise from your play and from your personal needs and experiences.

One of Squire's students in his dissertation study, an African American, became first intrigued by and then obsessed with the question of why African culture could not have become the dominant one globally, ahead of Europe. He worked diligently to answer this question and learned a great deal about the (unfair) distribution of resources around the planet, then wondered if he could create a conquering African civilization despite the disadvantage (and he did) (Squire, 2004). *Civilization*, like Duckworth laying out the uneven straws before Kevin, provided clearly defined goals; visible, measurable feedback; a compelling underlying model of the world; and an environment in which there are consequences to decisions (Squire, 2004). The personal efforts of this student resulted in a wonderful idea and the beautiful phenomenon Lantz is looking for.

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Finally, we have to recognize the possibility of draining this richness, this beauty, from games as experiences, particularly in institutional contexts where games might be made mandatory. We must acknowledge that cultural artifacts of all kinds may be used in ways that defeat their initial purpose, that misunderstand them. We must also acknowledge that players of some of the most amazing games may opt to play games in a way that is not fully committed. Suits (1990, p. 58) calls these folks "triflers," saying, "A trifler at chess is a quasi-player of the game, who conforms to the rules of the game but whose moves, though all legal, are not directed to achieving checkmate. … I think it is fair to say that such a person is not playing chess, although it is clear he is operating within the institution of chess." These players are no longer playing the game, but rather are acting within "the institution" of the game instead. In our minds, this is a natural part of play, embodied in the freedom of effort Osterweil has highlighted. Sometimes we don't want to play. Sometimes we wish to compete, and other times we would rather trifle. The material affordance of some aspect of the game might attract our attention, calling for us to play with it in some new way. Educators who are interested in using games for learning must understand that this is also how games and play do their work—players may not notice a particular property before they play in and around a game. The game may not resonate with them until they come to understand the world around that newly intriguing feature of the game through play. That is learning.

Games and School

In 1984 Seymour Papert wrote, "There won't be schools in the future. … I think the computer will blow up the school. That is, the school defined as something where there are classes, teachers running exams, people structured in groups by age, following a curriculum—all of that" (p. 38). In the thirty-plus years since, computers have been "oversold and underused" in education (Cuban, 2001) and, more to the point, have made the bureaucratization of schools easier and more complete. As we write this, schools are being pressed into buying more computers so that students can take PARCC and Smarter Balance standardized tests even though the No Child Left Behind Act, which reauthorized the Elementary and Secondary Education

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Act, was itself not reauthorized, and its replacement, the Every Student Succeeds Act, may seriously deemphasize such tests.

Of course, Papert's optimism was founded on changing society for the better, hoping to turn our societal project of education into something more humane, more focused on the good life. And computing is enabling novel educational experiences in many compelling ways. Scholar and activist Ivan Illich wrote about "learning webs" in his *Deschooling Society* (1971), stating that technology would allow for a society in which skills are shared and peers can be matched with one another, and in which individuals could be referred to educational objects and educational experts when needed. These practices have been researched and described by researchers in the digital media and learning community, in works like the *Connected Learning* report and books like *Hanging Out, Geeking Out, and Messing Around* (Ito et al., 2009; Ito et al., 2013). Young people (and others) are seeking knowledge online, sharing knowledge, exploring tools and processes for self-expression, and seeking out mentors when needed. The technologies that permit this have been predicted by progressive educational visionaries, but the social and institutional properties of contemporary education have limited whatever capacity technology may have had to "deschool society."

Many designers, developers, and researchers of educational games have opted to pursue learning communities outside or after schools. We have performed our own case study that illuminated the remarkable challenges inherent in school adoption (Klopfer & Haas, 2012). Yet we remain deeply committed to working with and in schools as they exist. This is a crucial piece of resonant game design—a game cannot fully resonate if it cannot connect with students, educators, and their communities, and if it is not adopted. This is, in part, an equity issue. If we wish to provide quality learning opportunities for young people who need it the most, then we must work with schools, as these students are the least likely to be part of a parent-organized informal learning community or home schooled.

Schools are an important institution, and they have transformed over time, bending to suit political purposes and to accommodate new understandings of what may be best in education. Graham (2007) describes phases in which schools were called on to manufacture an American identity for a nation of immigrants, to educate the whole child, to help children fit into society, and to outachieve other nations. David Tyack and Larry

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Cuban (1995) describe a process of "tinkering toward utopia," in which schools have undergone change after change to deliver a great education to all children. Since the federal government was essentially forced to intervene in schooling with the *Brown v. Board of Education* case, the government's work has been principally to bolster achievement and equity. In recent years, we have seen that concern get baked into legislation (the 2001 reauthorization of the ESEA). This movement has led to some excellent outcomes, as scrutiny has been applied to states and school systems that were systematically and deliberately marginalizing students. Yet, regrettable consequences have arisen from the pronounced achievement (i.e., test-centric) focus. There may well arise a new era of school experimentation in response to the recent past and to new legislation. What seems unlikely however, is that schools will disappear, as Papert suggested. We see the role of resonant design as one of anticipating and encouraging a new culture of experimentation within schools.

There are, of course, many challenges to creating successful learning innovations, let alone influencing a learning culture or learning cultures more broadly. Some known risks of innovating in classrooms are that schools and classrooms can coopt, deform, and otherwise marginalize or misuse a new piece of software like our learning games (Collins & Halverson, 2009; Cuban, 2013). And this is to say nothing of the deeply restricted classrooms under the contemporary era of standardization, high-stakes testing, and centralized control. We believe, though, that this is the best use of our efforts—to build a visible practice, drawing from the work of others and our own experimentation to promote dialogue and discussion. We strongly feel that this deliberate, intentional practice is our best hope for changing minds and even promoting a paradigm shift.

Clear or universal answers for the problems with our educational system might not exist, but part of the resonant games model is to develop an understanding of why and how games could be used in the classroom, as well as why and how they might not be appropriate. The changes in the policy environment are encouraging, but they will almost certainly not be a sufficient means to effect a full transformation of these conditions. In the near term, as we write, particularly in the chapter on *The Radix Endeavor*, we are very focused on working with teachers to provide them the support they need to take the risk of adopting our tools. In the far term, we support efforts to further professionalize teachers and grant them the training and

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full autonomy accorded to other professionals in society, as well as policies that allow greater experimentation in school culture and philosophy.

Games, Learning, and Design

In this book then, we further elaborate on the ideas that have formed the foundation of our game designs. The Education Arcade's approach to design research with our games and all our software and projects draws principally from the learning sciences and specifically the tradition of design-based research. Learning science is "a design science drawn from an engineering ethos. In an engineering approach, success is seldom defined in terms of theoretical accounts of how the world operates, but by developing satisficing solutions for how things ought to be—innovations that satisfy existing conditions and sufficiently meet the stated goals within prevailing constraints (Simon, 1996)" (Nathan & Sawyer, 2014, p. 23). Design-based research is about creating design experiments with some object in naturalistic contexts:

> Prototypically, design experiments entail both "engineering" particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them. This designed context is subject to test and revision, and the successive iterations that result play a role similar to that of systematic variation in experiment. (Cobb et al., 2003, p. 9, in Barab, 2014, p. 151)

This process of developing a learning object with careful attention to existing theory and an intent to report our findings back to the community is our fundamental underlying approach for developing resonant games. It is highly similar to the values at play framework (Flanagan & Nissenbaum, 2014) as well, iterating as much as possible and checking to ensure that the game is faithfully retaining our desired values at each iterative pass through the design process. During these iterations, we may cut systems we like, throw out designs whole cloth, or change our ideas about desired outcomes if the project warrants it. We may make tradeoffs with the principles we are advocating in this book, or we may change the attention given to any specific principle. We might dramatically reduce a multiplayer social emphasis in favor of more opportunities for deep inquiry if appropriate, or we may sacrifice authenticity of content in order to provide a much needed model to prepare for future learning. But it is fair to say that, for resonant design, we are most hoping to connect with the players.

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Throughout this book, then, we attempt to tell you not only about the finished product of each game, but something about how it was developed. When we were unable to iterate as frequently as we would have liked, we will give you some idea of what we would have changed and what ideas we could not fully pursue but believe bear further pursuit in other works and forms. In this way, we are trying to develop what Sasha Barab (2014, p. 165) has called, "storied truths," unpacking the ways in which our designs work in enough detail that others may implement those designs or ideas in their own local ecosystems. We hope that you enjoy our stories about our designs, and that you can find something you can use or adapt to help foster play and learning wherever you are.

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3 In a Game, You Can Be Whoever You Want to Be

Play enables us to rearrange our capacities and our very identity so that they can be used in unforeseen ways.

—Stephen Nachmanovitch

In different ways, scholars have talked about games as protected spaces, separated from the concerns or pressures that occupy us in the "real," that is, non-game world. Stephen Sniderman talks about a game's *frame*. Katie Salen and Eric Zimmerman, borrowing a phrase from Johan Huizinga, talk about the *magic circle*. Inside the magic circle, we are all free to play, constrained only by the game's rules and, of course, those ethical and social norms we won't violate, even within a game. What interests us for the purposes of this discussion is the freedom of identity that players exercise within the magic circle. In a game, you can be whoever you want to be (provided it doesn't break the game).

It is striking to us that within a game, so many players are fiercely determined, persistent problem solvers, an identity they adopt for the duration of the game, but one they often leave behind when they exit the magic circle. Why are so many children who are committed game players unable to commit to school? Are these players simply lazy, unwilling to apply themselves to any other pursuits besides games? Are they unimaginative, unable to see how traditional schooling offers equally engaging challenges? As may be obvious, these are straw questions, and we reject the idea that children are fundamentally lazy or unimaginative. Rather we see two deficits in the larger system that contribute to this disconnect between committed play identities and indifferent school identities. The first is that we rarely offer students in school problems to solve that are as engaging or relevant to them as their games, and the second is that we fail to

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reinforce or validate the problem-solving identities students form in their game play.

When we plead for more relevant and engaging schoolwork, we're not simply asking that students be better entertained. We understand that to succeed students must learn to apply themselves to problems with uncertain outcomes and the promise of at best delayed gratification. But if we present algebra, or biology, or history as devoid of any meaning in students' real lives, we are in effect telling them that school is a place where they will be rated on the performance of unnecessary tasks whose only purpose is to sort them for future rewards. Some students may be sufficiently acculturated to the "game" of school to want to perform these tasks for the promised rewards, but in the end, school performance winds up being a measure of that acculturation. Qualities like curiosity, passion, or creativity may be of little value to students trying to perform many school tasks.

So in an ideal world, school would be full of more meaningful activities. Note that relevance is not limited to those themes or topics that students are already interested in. If a problem is presented in ways that spark student curiosity, it becomes relevant. If students learn about real-world problems related to such topics, they become relevant. If topics are embedded in narratives that evoke empathy or excitement, they also become relevant. Challenges of intellectual or emotional depth have the possibility of becoming relevant to many students (though no one activity will be relevant to every student).

And of course, many good teachers and some good school systems are working hard to make academics more meaningful to their students. But even in such environments, students arrive with a range of prior experiences and cultural influences. Too few have been rewarded for their problem-solving abilities. Strong research evidence shows that students perform better when praised for their persistence rather than for their intelligence, but the prevailing culture celebrates talent, as if it were naturally endowed, God given, or somehow magic, rather than something accessible to all students. If only all students could have the experience of seeing themselves as hard working and accomplished. Or rather, if only they could see their game-playing identities merge with their academic identities.

Lure of the Labyrinth, funded by the US Department of Education, and designed by the Education Arcade working in collaboration with Maryland Public Television and Fablevision, was an attempt to give middle school

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students the opportunity to apply their game-playing skills to pre-algebraic math, and in the process shift their identities to nascent problem solvers, mathematicians, and scholars. Designed as an online long-form puzzle adventure game, *Labyrinth* is also an attempt to use games to nudge the culture of school in the direction of greater relevance, and maybe even help teachers recognize capabilities in their students that often go unrecognized in traditional classroom settings.

In the process of describing *Labyrinth*, we also discuss the following principles of resonant games:

- Cultivating player identity
- Scaling across time, space, and users
- Preparing for future learning
- Deepening complexity
- Guiding reflection

Settling on an Approach

Labyrinth was funded under the US DOE's Star Schools program, and it had several ambitious, overlapping goals. The game was primarily meant to address middle school mathematics (pre-algebra), but it was secondarily focused on literacy. Its intended audience was underserved populations, and since Maryland Public Television was the recipient of the grant, it was tested in schools in urban Baltimore and in rural parts of the state. We anticipated developing *Labyrinth* for game platforms accessible to the target audience, and if possible, the game was to be collaborative and multiplayer.

Early in the process, we held a series of meetings with Maryland math teachers to assess their needs, and from these meetings we drew an additional set of requirements. The teachers made it clear that they were unfamiliar with games in the classroom, were skeptical about their effectiveness, and because of curricular pressures were not sure how much time they could allot for game play during the school day. In addition, they were anxious about the introduction of any new technology into their classrooms because they could not afford the time to break in anything new and buggy, and because they were uncomfortable introducing any technology that they themselves had not mastered. And of course, they doubted they would ever master games. Despite all these cautions, the teachers acknowledged

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that they had trouble teaching some core concepts in the curriculum, such as proportionality, bases, and fractions, and that they would welcome any new tools to help students master those concepts.

One element that makes design, including game design, an interesting discipline is that designers often find themselves trying to design solutions that reconcile seemingly irreconcilable conflicts. In this case, serious needs weren't being met by traditional means of instruction, but multiple obstacles militated against using games in the classroom. (We want to be clear here that these obstacles are systemic, not simply the fault of teachers.)

Fortunately, in the system's resistance to games, we also saw an opportunity. In our prior work, we had observed that when children were imaginatively engaged in a game, playing of their own volition, they enthusiastically solved the kinds of complex problems that they rarely encountered in the classroom. In a subsequent chapter, we talk about the role of imaginative engagement in sparking kids' deeper learning, but suffice it to say we believed that children would do better work while playing games without the heavy hand of school resting on their shoulders. So the challenge we took on was to design a game that could largely be played outside school, one that bore little resemblance to traditional curriculum materials, but that could nevertheless have connections to the classroom and be of value to the teacher.

In thinking about an out-of-school game, the first question we had to resolve was what game platform? In 2006, when this project began, plenty of studies suggested that the digital devices most common in underserved homes were game consoles, such as the PlayStation or Xbox, or the smaller handheld equivalents, such as the Nintendo DS or Sony PSP. We knew from the outset that these would not be an option. Developing games for these systems required purchasing a costly license from the device manufacturers, and even if we could have afforded the multiple licenses required to cover all the options, the manufacturers were not prone to sell license for "educational" games, which they feared would weaken the image and cache of their devices (a sad commentary on the status of educational games).

So if dedicated game consoles were out, we were left with personal computers—smartphones did not exist. And yet PCs were not sufficiently prevalent in the homes of our intended players. We knew, however, that most students had access to computers in computer labs, afterschool programs, and libraries. Most of these computers would be Internet enabled. If we created a web-served game it would have several affordances:

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• We would not have to deal with the barriers found in many schools to downloading and installing new applications.
• Students with log-in identities could continue the game on any machine they had access to.
• There were possibilities for multiplayer games.
• We could aggregate student data in ways that might be helpful to teachers.

This was at a time when Flash had come into its own as a development environment. Flash plugins worked with every browser, and most institutions had already installed them. Flash had the computing and graphic capabilities we needed to create an attractive and immersive game. Although no solution would bridge the last mile into every student's home, this approach would reach the largest possible number of students, and with home Internet penetration increasing, the game's reach would only continue to improve.

Labyrinth was designed as a long-form game, requiring twenty hours of game play to complete. We hoped that its involved plot about monsters and kidnapped pets would excite players' imaginations and empathy, and in the process become relevant to them. Because it was set in a factory, we thought we could develop puzzles in which numerical and mathematical functions would be embedded within the workings of the factory, making concrete what is usually abstract in math instruction.

The Story

When players first log in to *Labyrinth*, they are immediately asked to pick a pet from a set of ten choices (figure 3.1). Along with the typical cute dog or cat, they can pick more unlikely choices, such as a skunk, a porcupine, or a pig (named Rover). In this, the very first game action, they begin to assert their own identities through the pets they pick, whether cute, fierce, or just a little weird.

Once they've picked their pets, players are launched into the story, which is told in comic book form. It is a dark and stormy night, and their avatars are taking their chosen pets out for a walk. Because of the weather, each avatar is wearing a hooded yellow rain slicker. The gender and ethnicity is left entirely to the player's imagination.

Players leave their pets tied up outside the pet store as they briefly step in to buy more pet food. While they are inside, a monstrous-looking character

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Figure 3.1
Asserting identity by selecting a pet

lures their pets away with a tasty treat, and when they come out, their pets are gone (figure 3.2).

The players' avatars follow the footprints, which lead to a sewer pipe and through that to a vast and mysterious underground space, in which they promptly get lost. Fortunately, a young woman appears and offers to help. Though she is blue skinned and winged, they have no choice but to trust her. She explains that the pet has been kidnapped by monsters, and to get it back, the player will have to infiltrate the underground factory that is the monsters' lair. She invites players to don monster costumes to be safe. Again, players are given a chance to assert their identities through the costumes they pick. There are forty-eight possible costume combinations, and the identity they each choose will be theirs throughout the remainder of the game (figure 3.3).

Most of the characters in the story emerge from worldwide mythologies. The young woman helping players is eventually revealed to be Iris, the daughter of Hermes, but we don't limit ourselves to the Greeks. Monsters from Mayan, Chinese, and Indian mythologies also make appearances. In creating a world that may activate young players' imaginations, we hope to increase their investment in the game's outcome.

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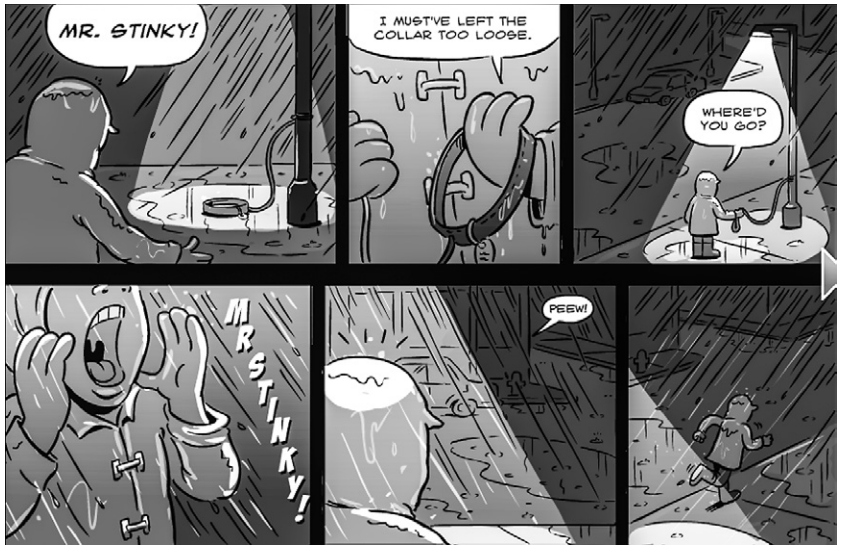

Figure 3.2
Beginning the search for the lost pet

Figure 3.3
Further asserting identity by choosing a monster disguise

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Following Iris's instructions, players enter the factory and present themselves to the HR (Horrible Resources) Department. From there they are assigned a series of jobs, each one taking place in a different location, and each representing a different mathematical puzzle to crack. There are twenty-seven puzzles in all. While on the job, they discover that many pets have been kidnapped, and that the monsters have a plan for world domination. In the course of the game, players free hundreds of pets, including their own, and foil the monsters' fiendish plot.

The storytelling is done with a fair measure of humor. Although players will be called on to thwart the monsters' machinations, we try to avoid the sodden adolescent fantasy that too many video games traffic in, that of the emotionally distant superhuman hero who saves the world while toiling in isolation.

Games aimed earnestly at kids tend to fall into one of two traps in the way they address their audience: they are either flattering or patronizing. Flattering games tend to portray the player as cool or superhuman, taking a quick and easy route to wish fulfillment. Unfortunately, adult attempts to portray "cool" usually ring hollow to kids. And while we all may occasionally fantasize about being all powerful, as we mature, we come to value problem solving over storybook omnipotence. Indeed, in the best games, we experience our potency through the hard problems we master, not through any superpowers the games may give our fictional characters.

Patronizing games take the route of assuming too little of players. In these game worlds, everything is cute and free of dark narrative threads. Games designed for educational settings are particularly guilty of this approach, the designers apparently afraid of injecting anything that any adult could find objectionable, and equally afraid of challenging kids with genuinely thorny problems. It's always sunny in these game worlds, and frankly a little boring.

In *Labyrinth* the world can be somewhat dark, and players are represented as just regular kids prone to errors and setbacks, who nevertheless eventually succeed by virtue of pluck and determination, and with the help and support of others. These story elements mirror our hope for the players: that they will succeed in school and in life through perseverance and collaboration. To quote the experience of Lynette Barr, a teacher in Australia who, inspired by *Labyrinth,* built a whole curriculum around using games:

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The students in 5/6B began the year looking for the "right" answer, or the answer they thought I might be looking for, during any given task. It has taken some time, but this mindset has changed throughout the year as students learned to tackle open-ended questions, solve problems without explicit instruction, take risks in their learning and accept that their teacher will not provide them with all the answers but will instead learn alongside them.

During this trial the student/teacher dynamic has changed as students became familiar with my teacher-as-facilitator approach. Labyrinth has assisted with this transition because it is truly student driven, and my role as a facilitator meant I could provide varying levels of support, modeling and explicit teaching to individuals, small groups or the whole grade in response to the needs of the students.

My teaching practice has continued to transform and evolve with the GBL [games-based learning] approach I am taking with my grade. I am witnessing an increase in the depth of student learning taking place in maths and, subsequently, in other areas of learning. Dealing with student misbehaviour is not at the forefront of my practice when using LOTL [*Lure of the Labyrinth*] with my students because they are truly engaged in their learning and classroom behaviour is excellent. I take a back seat when students play LOTL and watch them drive their own learning experiences. This trial has reinforced my belief in my own philosophy for teaching and learning—powerful learning occurs when I am a facilitator for student learning, and a learner alongside them. —"Case Study of Lure of the Labyrinth," *Playing to Learn*, March 16, 2012, https://lynettebarr.wordpress.com/2012/03/16/lotlcasestudy/.

The Principle of Cultivating Player Identity
Trying on and exploring a new identity in a game space provides an opportunity for players to incorporate new aspects into their real-world identity.

When applied	*When not applied*
Students playing a game are free to explore a range of identities, to experience themselves as strong and capable, but also to explore flawed or even transgressive versions of themselves. Inside the magic circle of a game, players have the chance to imagine their best (and sometimes worst) selves in a safe space.	Games that don't accommodate exploration of identity too often flatter or patronize. Flattering games assume the player wants only to adopt wish-fulfilling roles, while patronizing games try too hard to be cute or nice.

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Puzzles

After describing a typical *Labyrinth* puzzle, we discuss the principles that animate our puzzle design. In our example, "The Employee Lounge," HR sends players to the break room, where they meet a large green gelatinous blob of a monster. Totally lacking in appendages, it asks them to do it a favor and get it something out of a vending machine. That's all the information they have when they arrive at the game screen shown in figure 3.4.

Typically, players start exploring by clicking on the food items or the numbers below them, but the game is unresponsive. Eventually players discover that they can pick up the colored disks/blinking eyes in the lower right of the screen. Some players try to place the disks on the food items but get no response. Eventually they figure out that disks will fall into place with a pleasing "pop" sound when set in the circular spaces on top of the machine. Once three disks have been placed, one in each spot, they fall into the machine with a satisfying "ka-ching," and a food item drops out of its position and lands below. After that, symbols and numbers appear in the

Figure 3.4
"The Employee Lounge" puzzle

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upper right black space. The picture shown in figure 3.4 represents the typical results of a player's first move. In this instance, the player placed green, pink, and blue disks in that order, left to right, and the item that dropped out was in the slot marked 13. (Because this is a monsters' lounge, the food in the vending machine is humorously disgusting. The delivered cupcake has an eyeball in the frosting.)

Typically, many players' next move is to try the same three colors in a different sequence. The result is no additional food dropping out, while the symbols in the upper right again mirror the pattern of disks placed in slots, and again equal the same number as before.

Players may do this several more times, but most eventually have the insight that maybe the disks are coins, and maybe each one has a different value, adding up to the cost of the food item dispensed (and the number displayed upper right). Once they've made that realization, they hit on the strategy of depositing three coins of the same color. Inevitably, this results in a value that is a multiple of 3, confirming their hypothesis. Once they have constructed this model of the system, they are on the road to solving the puzzle.

The complicating factor is that after three tries, one of the food items starts flashing. If players fail on their next try to submit coins equaling the price of the flashing food, the puzzle shuts down. Only players who figured out the system after one try have gained enough information to succeed. But if the puzzle shuts down, players are free to replay it immediately. The next time they play the puzzle, however, the coins will all have different values. In other words, the puzzle is not about figuring out what the blue coin is worth, but about figuring out a strategy for solving for all values.

When players have displayed mastery by solving this puzzle three times, they graduate to another version of the puzzle, one in which they have the same limited number of tries but can no longer put three of the same color in the slots. The puzzle is still solvable, but it requires players to explore more deeply what they can deduce from different patterns of numbers.

As may be apparent, this is a game about algebra, about "solving for x," though we never use the word variable or call attention to the concept. Like all the puzzles in *Labyrinth*, it invites players to explore a system that

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initially seems opaque, but that reveals itself through probing and experimentation. In the process, the player begins to construct a model of the system.

This puzzle is an illustration of what we mean by relevance. We give the players an interesting problem, one that feels analogous to the real world even as it is embellished with the fantastical. These kinds of problems are not foreign to players from their game-play experiences, even if they bear little resemblance to the way algebra is taught in school.

This example is also an illustration of what we mean by depth. Every puzzle in *Labyrinth* is procedurally generated—every time it's played, there is a different, randomly generated solution. To advance, the player must solve it three times. The first time players solve a puzzle, they are often just beginning to grasp the underlying model. Solving it a second and third time gives them the opportunity to solidify their mental model and take pleasure in their growing problem-solving abilities.

Having successfully solved a puzzle three times, they should be ready for us to further complicate the challenge and deepen the complexity of the model. Every *Labyrinth* puzzle has three levels of difficulty, and as they work their way through them, we hope that players are developing ever more sophisticated models of the embedded concepts. Our goal is not simply to have players demonstrate mastery of a limited number of mathematical procedures, but rather to build robust cognitive scaffolds, and to become increasingly confident in their own reasoning processes.

"The Employee Lounge" is one of nine puzzles, and each puzzle has three distinct levels of difficulty, for a total of twenty-seven puzzles to be mastered. Topics of other puzzles include proportionality, fractions, modal arithmetic, alternate bases, vectors, and the relationship between the area and the perimeter of a rectangle.

In addition, puzzles all take place inside "rooms" in the factory, and to play a puzzle, players must first find the room. This involves deciphering maps, which themselves represent mathematical challenges related to number systems, Cartesian coordinates, and fractals (figures 3.5 and 3.6). As the puzzles increase in difficulty, so the maps grow increasingly obscure and more challenging to interpret.

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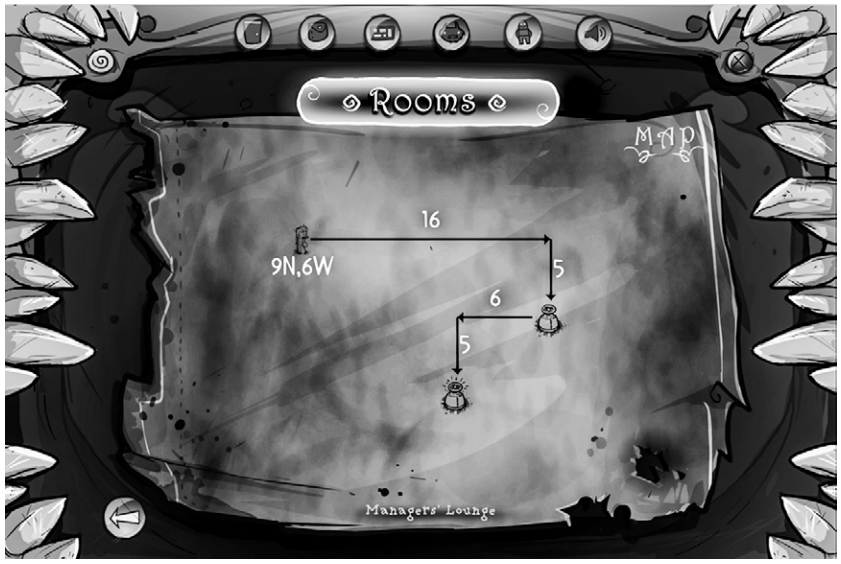

Figure 3.5
A map based on Cartesian coordinates

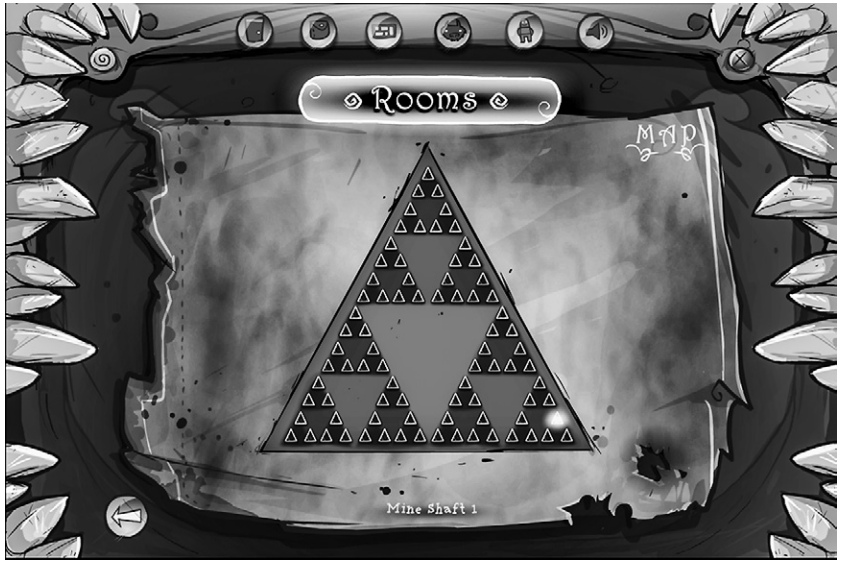

Figure 3.6
A map based on fractal Sierpinski triangles

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The Principle of Deepening Complexity
Deep learning can be supported by designing levels or sequences of tasks that increase in complexity in interesting ways, challenging players to experiment further.

When applied	*When not applied*
Games with deepening complexity introduce concepts that are challenging and that may not lend themselves to quick or easy explanations. They enable players to build mastery through repeated exposure to these concepts while gradually introducing new dimensions to be wrestled with.	Games without complexity will offer only limited opportunities for players to engage with a concept. Players aren't challenged to take what's learned in one place and apply it in another.

Game Structure

As deep and satisfying as we hope the *Labyrinth* puzzles are, giving players an assemblage of interesting puzzles isn't sufficient. The design of the game's overall structure is also critical. The structure determines the multiple paths players have to achieve their goals as well as the nature of the incentives they receive for that achievement. Incentives include points earned, feedback about levels of mastery, and the players' advancement through the game's story. *Labyrinth* is structured to encourage both freedom of exploration and persistence in the face of difficult challenges.

Even in unsuccessful attempts to solve puzzles in *Labyrinth*, the player earns points (called "credits") that will accumulate toward winning the overall game. In other words, some credits are awarded simply for effort, though more are awarded for success. The purpose of these partial rewards is not to make the player feel good, but rather to honor the fact that the player persisted, that problems can be solved only through repeated effort, and that strategies learned from unsuccessful attempts usually lead to eventual success. Repeated failed attempts may cost the player time, but they don't otherwise impede the game. Indeed, players usually need to collect several failures just to acquire the information they need to solve each puzzle. The game makes it easy to replay a puzzle immediately after a failed

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attempt to smooth the way for the kind of iterative problem solving often demanded of us in real life.

In fact, a player could conceivably reach a conclusion of the game by accumulating credits entirely through unsuccessful play (though this would take significantly longer than the twenty hours of game play we expect). This is not to say that we don't provide incentives for genuine success. Players who play and beat every puzzle will get to the end of the game much quicker, with tangible markers in the game that they've played well. But no one is penalized for mistakes (except for lost time), so every player who eventually solves a puzzle ends up with an equally high score. The game puts a premium on problem solving, not on speed.

This structure also enables players who feel stymied by one puzzle to put it aside and pursue success in other puzzles. Players are free to follow their interest and curiosity into whatever part of the game excites them most at the moment. Real learning is driven by interest, and interest in every player will be different and idiosyncratic. Today I may be intrigued by one puzzle, tomorrow by another, and the game allows me to follow whichever path is calling to me now.

Through the course of game play, players are accumulating credits. In turn they can use these credits to buy items that they use to free pets trapped in the factory. The accumulation of credits is also what triggers new chapters in the game's narrative as well as new revelations in the mystery at the center of that narrative. Over time the game world gets more expansive as new rooms are opened to the player, and it also gets deeper as the complexities of the story are revealed.

Creating such a broad and deep world was always a significant design goal. We wanted the game world to feel "large," so players' imaginations would be stimulated, and their investment in the outcome would be strong enough to motivate them even when the going got tough. Small games can of course be artful and engrossing, but when done well, epic games invite players to make a deeper commitment; when one's friends and classmates are simultaneously playing them, they acquire even greater relevance.

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The Principle of Scaling across Time, Space, and Users
Game experiences often become deeper and more meaningful when they are played over time, with people across distances, and with large numbers of other players.

When applied	*When not applied*
Games can inspire deeper engagement in players when they are experienced on a grander scale. Whether they involve many people playing at once, epic narratives, or many hours of play time, such games signal to players that their deeper investment of effort will be rewarded commensurately.	Games that have limited scale can nevertheless be engaging, but they are less likely to inspire players to engage deeply. There is certainly a role in people's lives for casual play, and casual play involving challenging ideas can also foster learning, but it is harder in such contexts to spark the imaginative engagement that an epic experience can.

Pedagogy

As is evident from "The Employee Lounge" puzzle, the game is not "curricular." It doesn't cover all the material one would find in a textbook chapter, nor does it attempt to instruct students on traditional procedures or algorithms used when "solving for x." In fact, we wouldn't expect most students who play this game to automatically see the connection between the game and their formal math instruction. But we do think that by playing the game, they're doing important work. In response to the mysterious phenomena they encounter in the game, they initially probe (clicking around the screen) and observe (what actions work, what feedback do I receive?). What starts out as trial-and-error exploration gradually evolves into more organized testing of hypotheses, and along the way, they learn practices like controlling for variables in their testing. They are learning how to model systems in order to make sense of them. And they are building mental models of certain specific mathematical concepts.

The process of modeling described above actually occurs in any game that's sufficiently challenging, and yet we know that dedicated gamers don't automatically adopt the identity of scientists or engineers even if they are mastering analogous problems through their game play. We also know that playing interesting games won't make everyone a good student. We believe that only through continuing to work with the models they've constructed will students solidify the understanding they've been

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approximating through their game play. Fostering this continued engagement with the concepts learned in games remains a critical role for educators in the process.

So imagine a teacher walking into class one day and projecting "The Employee Lounge" puzzle on the whiteboard. Because she can see logs of online activity, she happens to know that most of the class has already mastered this puzzle. She knows that a student who hasn't participated much in class discussion was actually quick to solve it. So she invites that student up to the front of the room to describe her strategies for solving the puzzle. Other students also volunteer their strategies, and a discussion follows about both the particular puzzle and problem-solving strategies in general. The design of *Labyrinth* makes it easy for teachers to access discrete puzzles within the game to facilitate this kind of classroom discussion whenever it aligns with the class's given curriculum.

In traditional math classrooms, the introduction of each new topic—like variables—is an opportunity for more students to get left behind, to finally decide that they're "not good at math," as most students will conclude by the time they graduate high school. And once they get left behind, they rarely catch up again. In the story above, before the topic of variables is introduced, students have actually mastered the process of solving for x, and they've done it in a relevant context. So when the teacher introduces variables, she's not throwing a new obstacle in her students' path, but rather she's building on their hard-won expertise. The classroom discussion becomes an opportunity to solidify the understanding students may have begun to acquire through game play but have not yet connected to the formal procedures of mathematics.

In the above example, the teacher is also learning. From looking at the player logs, she's discovered that a quiet student is actually engaged and capable. Through the logs and the ensuing classroom discussion, she learns more about the competencies her students bring to the work, and about their ways of thinking about problems. It is an opportunity for her to give positive reinforcement to her students for their persistence and for mathematical reasoning they've displayed. It's also an opportunity to provide further attention to any areas of weakness that may have been revealed.

Of course, this entire discussion turns on a hypothesis of how learning concepts can be initiated through game play and fortified through

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classroom experiences. Initially, we intuited these ideas through our own experiences of learning and game playing, but they have been supported in the research literature and characterized as *preparation for future learning* (Schwartz et al., 2005). Building on earlier work by Harry S. Broudy (1977), preparation for future learning focuses on "interpretive knowledge" and the ways in which prior learning experiences, when they are experientially rich, can give learners the interpretive tools to make sense of new problems. Even when learners have forgotten all the factual details, or content, of a prior learning experience, if they've had opportunities to build robust mental models, they are better prepared to learn new concepts when they encounter them.

In one study that supports this approach (Schwartz & Martin, 2004), researchers divided learners into two groups. One group was given reading material about a specific concept, and the other group was given a hands-on experience that enabled them to explore the concept much the way our games enable students to explore concepts. Each group was further subdivided in two, with half of each group subsequently hearing a lecture on the same concept, and the other group getting no further instruction. All groups were then assessed on their understanding of the concept. The group that had only the hands-on experience fared the poorest on the assessment. The two groups that started with reading did about equally well regardless of whether they received further instruction. But the group that followed the hands-on experience with formal instruction did significantly better on the assessment than any of the other groups. The earlier exploratory experience had better prepared the students to truly learn the concept in a more formal context.

We would never claim that playing a game like *Labyrinth* is all that's required for a student to learn a concept. Rather we see game play as the kind of engaging and relevant experience that leaves students prepared to make fuller sense of the concepts they've begun to master when they encounter them again in school, or in their daily lives.

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The Principle of Preparing for Future Learning
Experiences in which players construct their own knowledge form a solid foundation for subsequent learning activities to build on.

When applied	*When not applied*
Games prepare players for future learning when they promote conceptual understanding through exploration, rather than mere acquisition of factual knowledge. The former equips the player to ask interpretive questions when confronted with new challenges, while the latter can often prove to be ephemeral.	Games that invite players to exercise their knowledge of facts or procedures can provide positive reinforcement for students who are already comfortable with a subject, but they are less likely to prepare students for new challenges.

Collaboration and Reflection

We've already discussed the critical role that classroom experiences can play in solidifying a student's understanding of mathematical concepts first encountered in games. As important as we believe the classroom is in this process, we also believe that learning can be fortified through collaboration with other students, and through self-reflection. As we designed *Labyrinth* we kept thinking about how gamers often engage in fairly sophisticated conversations about their strategies in game chat channels, in game FAQs, and in fan forums (Steinkuehler & Duncan, 2008). For example, students who show no interest in writing in school will sometimes write elaborate, well-constructed walk-throughs of games for an audience of their fellow players, because this audience has meaning for them. The culture among gamers is one of reflection and collaboration, even if gamers might not label it as such.

We therefore wanted a way for *Labyrinth* players to engage in similar behaviors. The most direct way of fostering this would have been to make *Labyrinth* a multiplayer game with a built-in live chat system, like *World of Warcraft*'s. For several reasons, however, this wasn't possible. Multiplayer games are much more expensive to build and maintain, which would have strained the limited resources of the grant. Of equal significance, creating an open online environment to be used by middle schoolers would have had serious issues. Parents and teachers are understandably concerned about who children of that age might encounter in unmoderated spaces, and laws limit what can be offered to children younger than age thirteen.

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We firmly believed that some form of collaborative play was desirable, but for such a game to be adopted widely, it would have to be a walled garden, where students encounter only students they know personally. And since there are opportunities for mischief in even such bounded environments, it would have to be a space that teachers could monitor with relative ease.

We had a second reason for wanting some form of collaborative play, beyond its benefits for learning math. A subsidiary goal of *Labyrinth* was to have a positive impact on student literacy. The choice of comics as a storytelling mode was part of this strategy. But we also believed that if we could inspire students to read and write about their mathematical reasoning, it would influence their reading and writing as well as their reasoning.

As much as we desired collaborative play, we knew about additional constraints related to the lives of the students we were most interested in reaching. Remember that we were designing for use after school, and for a platform (the Internet-enabled computer) that was not in every home. We presumed that our target audience didn't necessarily have adequate control over their own schedules to guarantee that they could play online at the same time, so the game would have to work when played asynchronously.

Our solution was to enable teachers to put the students in their classes on teams of up to six players, and we suggested they set up a friendly competition between teams to get the highest score. Although all students would be playing the game on their own, they would have incentives to help their teammates succeed as well. To facilitate this, we built into the game a messaging system, but one in which students could see only the messages of their teammates. We imagined students would use this system to ask each other for help or to share successful strategies. Since all the puzzles were procedurally generated, we knew students couldn't give each other "right" answers (every time they played, the answers would be different). But students could write to each other about their strategies, or try to explain to each other the underlying model for a given puzzle. Research consistently shows that when students have opportunities to teach each other, both the "teacher" and the "learner" benefit. Our hope was that the messaging system would become a major venue for collaborative learning.

Labyrinth is still widely used nationwide, but because of changes in federal funding in the midst of the project (the entire Star Schools program

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that supported *Labyrinth* was defunded), we've never had opportunities to adequately study the game in use. As such, we don't know how much players use the messaging system, though a small-scale study undertaken several years after the game's release suggests that the messaging is not used as much as we'd hoped. This may be because students within a class have plenty of opportunities to talk without depending on the messaging system. It may be because the students don't perceive that they'll get answers in real time, so they don't bother to use it. We certainly see the behavior we were hoping for in the live chat channels of many multiplayer games, so perhaps it would have worked better if students could have had live chat with the community of all players, but of course that wasn't feasible for reasons of safety and security already mentioned. Nevertheless, teachers report to us that the team competition motivates their students to collaborate, and they do see some interesting math talk from time to time in the chat channels.

Even when we are working to make robust, fully useable games like *Labyrinth*, we also see our work as design research, and we specifically saw the inclusion of chat as one of the more experimental features of the game. Our experiences with collaborative play in *Labyrinth* informed our subsequent work on *Radix* and *Vanished* (both described later in this volume), and we continue to explore it in much of our ongoing work.

The Principle of Guiding Reflection
Explicit reflection activities facilitated by a mentor can illuminate how far players have come and solidify what they learned from and enjoyed about the game play.

When applied	*When not applied*
A game fosters reflection when the game's design affords players opportunities to discuss strategy through in-game chat systems. Alternately, a game can foster reflection when it is structured in such a way that teachers can easily draw on discrete moments in the game for classroom discussions.	Any game that is challenging to a student provides the potential for productive reflection, but if the designers have not accounted for how or where that reflection will occur, they diminish its likeliness.

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Integrating Game Play and Narrative

In designing *Labyrinth*, we built on what we had learned from the development of an earlier game, *Zoombinis*, designed in 1996 by Chris Hancock and Scot Osterweil at the Cambridge research and development firm TERC, and developed by the respected software publisher Brøderbund. In particular, we pursued a similar structure for *Labyrinth*, one that makes it easy for players to persist with a puzzle through repeated play, but that also allows players to explore an epic space and apply their efforts wherever their interests or impulses lead them. As in *Zoombinis*, we created puzzles that require players to start with opaque challenges and gradually construct new models in order to eventually prevail.

Zoombinis was a very successful game in the marketplace, and we think in *Labyrinth* we created a game that was wholly original, but that built on what was learned from the creation of the earlier product. Nevertheless, one way in which we believe *Labyrinth* didn't fully match the success of *Zoombinis* was in the full integration of game play and narrative, and the reason for that is instructive about the design and development process.

Zoombinis is a game about combinatorics and the mathematics of data. The game actually emerged out of earlier work by Hancock and Osterweil on ways of representing data for young children. A classroom product they designed called *Tabletop Jr.* included little blue creatures whose traits (hair, eyes, nose, feet) were independently variable, like data records in a database. When Brøderbund asked Hancock and Osterweil to create a game based on these characters, the narrative that emerged was based on how the *Zoombinis*' characteristics interacted with the world they encountered on an epic journey. As such, the whole world of *Zoombinis* is a world full of structures related to data and data processing. The game narrative and the game play are fully integrated.

Creating *Labyrinth*, we didn't have the luxury of starting from clearly instantiated mathematical concepts, the way the *Zoombinis* already embodied ideas about data. Before we had opportunities to fully explore the mathematical concepts we would base the game on, we needed to develop a preliminary design document that captured the scope of the game and the underlying narrative so that the software development could be put out to competitive bid among several potential production partners. This forced us to commit to a narrative gambit before we had fully defined our

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mathematical ideas. We think that the narrative we developed is appealing to our target audience, and it justifies the inclusion of multiple puzzles, each embodying a different mathematical concept, but the larger story world did not fully embody those concepts.

After we had committed to a development partner and an overall approach to the game, we were able to further integrate mathematics into the larger game world through the maps the player uses to find each puzzle room, but the game remains a collection of good mathematical puzzles linked by a narrative and game world that is itself not fundamentally mathematical.

In an ideal design process, we might have had more time to develop the core ideas of the game before committing to a development plan. With *Labyrinth*'s focus on pre-algebra, we might particularly have looked to create a world that reflected issues related to ratios, proportions, and fractions. For example, in retrospect we can imagine a game narrative about a character who, like Alice in Wonderland, has to navigate a world in which items frequently grow or shrink, and more of the puzzles and the larger game world might have involved the proportional reasoning necessary to navigate those changes.

We bring this up not to lament the outcome of *Labyrinth*, a game we view as very successful, but rather to highlight the importance of a design and development process that, as much as possible, enables the design team to fully explore the ideas that will undergird the game. We strive always to create games that help illuminate what is authentically playful and engaging about their subject, and the more that design can occur before the high cost of software development kicks in, the more likely we are to fully realize our goals.

Conclusions

We've discussed how we designed *Labyrinth* to work in the particular academic environment we were given, one in which teachers were at best cautious about using games, and one in which students would not all have access to the same computers or game devices. We've also talked about how the underlying pedagogy of *Labyrinth* promoted collaboration, reflection, and most importantly, preparation for future learning (although it should be emphasized that the "preparation" is itself also a form of learning).

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It would be easy to conclude from this discussion that if we design a good game, and one that fits into the ecosystem of school, then somehow learning will automatically occur. That couldn't be further from our intent. No matter how well we work to ease the way for students to learn through well-designed, engaging games, our core belief is that students learn best when they choose to learn, when they're motivated and inspired to learn. Which brings us back to the question of identity.

We want students playing *Labyrinth* to master new math concepts and exercise literacy skills, but we particularly want them to experience themselves as capable problem solvers, learners, and collaborators. When they are confronted with a challenge that seems difficult or opaque, we want them to remember the value of probing, observing, hypothesizing, and leveraging wrong answers as necessary steps on the road to right answers. We want kids not to just see themselves as the superheroes and dragon slayers of childhood fantasies, but to take on an identity as members of a team of heroic problem solvers, the kind of identity they will all need to become lifelong learners and actively engaged citizens.

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4 "I Wish I Could Go On Here Forever"

The best scientist is open to experience and begins with romance—the idea that anything is possible.

—Ray Bradbury

A Game for Science Practice

In spring 2011, about six thousand ten- to fourteen-year-olds saved the world—kind of. They participated in *Vanished*, a game designed and developed to engage middle school students in the practices of scientists, allowing them to frame and solve problems scientifically. This, theoretically, then allowed them to adopt the persona and perhaps ultimately an identity as a scientist (or at least someone comfortable with science). The game was run in conjunction with the Smithsonian Institution's Center for Learning and Digital Access. The students were able to not only solve puzzles within the game, but also interact with Smithsonian scientists online and visit Smithsonian partner museums throughout the United States to find useful information and have meaningful interactions with museum educators and scientists in their community. By weaving these real experts and experiences into a fictional narrative, we produced an unforgettable experience.

The game arose from a discussion with the Smithsonian's Matthew Carrano. We had established a partnership and were hoping to teach young people about extinction and the threats that are arising from climate change. As the conversation turned to how we might do that, Carrano volunteered that he wished more young people understood that the scientific method didn't dictate his day or his work at all. His process sometimes started in the middle, or the end, picking up someone else's data or playing

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around with ideas and experimentation before eventually wondering his way back to a falsifiable hypothesis. His sense of wonder, he surmised, was a greater professional asset for him and his process of inductive hypothesis generation. He also shared that he wished students knew how social science is. Most of his day is spent sharing ideas or discussing findings with friends, getting excited together about some new puzzle.

Carrano's wishes couldn't have been vocalized at a better time. There was a new type of game emerging, the alternate reality game (ARG), in which players work in large groups to solve massive problems they couldn't solve on their own to advance a story being built by the game's developers. In games like *The Beast* (4th Wall Entertainment, 2001) or *i love bees* (4th Wall Entertainment, 2007), these problems, puzzles, or challenges would be disaggregated across the web or across physical space and would often require creativity as well as inductive excellence. Players' collective efforts would not only solve puzzles, but create a real culture of belonging and shared purpose. They also occasionally created key parts of the game, even if they didn't know it at the time, by generating theories or resources that the developers could use to make new puzzles. These games, in addition to being exciting experiences that charted a course for what the World Wide Web could be as a storytelling medium, were exemplars of how exciting social learning and creation could be. It seemed clear that this new form might be an excellent match for a learning game that suited the underrepresented aspects of science that Carrano had identified.

Further, the ARG format could help with a secondary problem as well—the Smithsonian has an important role as the national museum of the United States, but its rich collections and learning opportunities are largely rooted in Washington, DC. The main institution helps support the national mission through a national network of affiliate museums, but struggles to activate those relationships. One of the defining features of the ARG form is to balance extensive online play with localized events, which seem to build community as well as give the often paranoid worlds of these games a compelling physical instantiation. Puzzles from the website may reveal a place and time for a meetup, at which point players close to those physical locations attend events where new puzzles are introduced and solved on the spot or new information is released. These local players then bring this new information or the results of the puzzle or other engaging activity back to their online colleagues for further discussion and deliberation. It seemed

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as though, given the Smithsonian affiliate network, as well as the museum's developing collection of digitized artifacts, that an ARG could be a tremendous opportunity to bring the Smithsonian and its resources beyond the walls of their buildings in DC.

As we were beginning to stitch these ideas together, creating an ARG to advance the social and exploratory angles of scientific practice, Philip Bell and the Committee on Learning Science in Informal Environments published their "Strands of Science Learning," which outlined how informal venues for science learning like the Smithsonian could best play a role in the development of excited, engaged, and even skillful science learners. The sixth strand, indicating that learners should "think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science" (NRC, 2009, p. 4) would be the most relevant to our learning goals for *Vanished* as a whole, while the other strands would play a role in individual activities within the larger game. The convergence of the Smithsonian partnership, the emerging art form of the alternate reality game, and a careful, thoughtful framework for science learning created a rare opportunity to create what we came to call a "curated game." By providing a heavily scaffolded scientific mystery with tremendous input from Smithsonian scientists, curators, and educational staff, we produced a living exhibit that reached thousands of young people and greatly extended the reach of the museum.

The Design and Development of *Vanished*

Vanished was a seven-week ARG developed over the course of two years. The game allowed only players aged ten to fourteen and was primarily conducted through discussions in the game's forums, interactions with Flash-based games and tools on the game's website, and activities (scaffolded to varying degrees) in museums and science centers across the country. The game's central conceit was that the players had been contacted by people from the future who needed their help (principally Jasper, a representative of Project Phoenix). They claimed that some catastrophic event had happened between their time and the present, and they needed help from the players to determine the nature of that event as well as its consequences. While players would always be able to change the direction of the game through their creativity and interests, we built the game in advance of its

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run using weeks of the experience to function as tiered challenges (like levels in a video game), but also as a serialized release of content, like television shows, comic books, and the film serials of the early twentieth century.

To promote the game and gather an audience, we wrote articles for major publications, like *USA Today*, and advertised in a way that we never had before. Billed as the *MIT-Smithsonian Science Game*, players signed up with no idea what was in store for them. On the first day, players logged in to a video message. Undergraduates we had hired to function as moderators for the forums and role models for players informed the players that the game's servers had been hacked. The game was to be delayed, but perhaps the players could help. Within a few hours, players had noticed short bits of text flashing during the video. Within a few more hours, players had discovered that there was a large but finite number of these repeated texts and that they were ciphers, which the players began to decode. Within twenty-four hours, they had the entirety of the message translated.

Once we had the basic premise, the game unfolded largely in a logical fashion. If you were communicating with people from the future, what would you need to do? And what would they want from you?

Week 1. *Something's Wrong/Making Contact*: In this week, players are introduced to the game, the fictional contact from the future presented as a challenging distributed cipher.

Week 2. *Where Are We?*: In this week, players crowdsourced data about their local communities, uploading pictures and information about local weather, flora, and fauna. After discovering that the players needed to establish common units with their contacts, players performed extensive conversions for measurements of distance and temperature. Project Phoenix confirmed that the planet is much cooler in the future.

Week 3. *Where Are We?, Pt. II*: The players and their colleagues in the future still needed to establish a common coordinate system to share information about global positions. Players discovered that data passed by Project Phoenix were the locations and heights of the three tallest mountains on the planet, although all of the heights were off by about ten meters, meaning that sea level had risen. It was puzzling to imagine how sea level could rise without global warming, since it had been established that the world was much colder.

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Week 4. *What Has Happened?*: Players had to discuss and debate and develop a small number of tests that Project Phoenix could run to determine what could cause global cooling after global warming. Many ideas were discussed, including wandering magnetic poles, extreme volcanic eruptions, and a collision by an asteroid or other material, such as the one that is hypothesized to have rendered dinosaurs extinct. In the end, the players and Project Phoenix determined that it was likely the asteroid collision due to a new, outsized crater in the future.

Week 5. *How Could This Happen?*: This week students began to drill into why humanity would not have diverted the asteroid. Documents released through game play in *Vanished*'s various activities, including flash games, had begun to hint at cultish behavior in the Americas and technology backsliding by time of the collision.

Week 6. *Explore the Future, Save the World*: In this week, players attempted to understand the nature of this technological backsliding through the use of archaeological rovers in the future to uncover artifacts and settlement patterns from the eras preceding the asteroid strike. This allowed Project Phoenix to reveal that they were not actually humans in the future but alien scientists who sought to understand why the once inhabited planet Earth was uninhabited in their time!

Week 7. *Wrap-Ups And Farewells*: The players had learned the fate of the world and were now empowered to make a blueprint for avoiding that terrible future. Our fictional characters were given largely happy endings, and players, mentors, and game runners said goodbye to one another.

In this chapter, we emphasize four important design principles that were critical for *Vanished* and the role that they played in shaping our overall design thinking for this project. Those principles are

- Authentic problems
- Social design for learning
- Multiple pathways and freedom of effort
- Narrative and imaginative cocreation

In the sections below, we elaborate on how *Vanished* worked and what we were able to accomplish as a means of illuminating how these principles can function in designing a resonant game.

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Learning to Save the World by "Saving the World"

The Principle of Authentic Problems
Most games pose some sort of problem or challenge to be investigated and solved. Problems in the game that resemble the "real-world" problems that they model, situated appropriately, not only will likely produce more usable knowledge, but may also be more engaging.

When applied	*When not applied*
Resonant games with a compelling and authentic problem are more likely to be great learning experiences. Authenticity should ensure that the skills being developed and rehearsed in the game are near to those needed in the real world. Authenticity is not a function of whether a problem is served in a "realistic" setting, but whether the problem solving seems to have a purpose related to the story or setting in which the player is imaginatively invested. Authenticity also means that the problem students are engaged in is a problem that they understand and that relates to their real lives or their real interests (including fantasies) in some way. Even fantastic problems must take the inner life of the young person seriously.	Artificial or inauthentic problems may confuse or alienate players. If the skills being developed or used in the process of solving a problem feel inauthentic, they may make the activity feel arbitrary and thus controlling and alienating. Overly earnest problems ("Let's raise money for an imaginary community center by matching shapes!") may distract from real problems in the players' lives and provide practice for a legitimate skill without connecting to the players authentic inner lives. In other words, artificial problems may compel students to ask, "What is the point of this?!"

When planning this game, we knew the Smithsonian was focused on addressing climate change, on sharing their collections and resources more broadly, and on innovation, broadly speaking. The alternate reality game's history of attracting audiences driven to collectively investigate and solve problems seemed like a nice way to address these design specifications. But which problems should we choose? And how might we help students get the most out of their experiences?

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M. D. Merrill's "First Principles of Instruction" (2002) provides some guidance here:

a. Learning is promoted when learners are engaged in solving real-world problems.
b. Learning is promoted when existing knowledge is activated as the foundation for new knowledge.
c. Learning is promoted when new knowledge is demonstrated to the learner.
d. Learning is promoted when new knowledge is applied by the learner.
e. Learning is promoted when new knowledge is integrated into the learner's world.

We would attempt to meet players where they are, and although players would be operating in a narrative context, we would ground as much of the narrative as we could in authentic problems. These problems would need to feel real to the players but also be approachable by people aged ten to fourteen.

Climate change seemed like a prime issue to structure our problems around, because of its ubiquitous discussion and its looming character—our audience would almost certainly be dealing with the effects of climate change over the course of their lives and were probably aware of this fact in at least some cases. We weren't convinced that we could make *solving* climate change very compelling though. Experts like Jane McGonigal had already attempted something similar through games in which players imagined their responses to bleak alternate futures, like *A World Without Oil* and *SUPERSTRUCT*, to what seemed like mixed results. While there are undoubtedly benefits to games like these getting people to imagine alternate futures, it was unclear that our audience would have enough context to make moves within our story that would satisfy themselves and us as experience creators. It became clear early on that we could create a compelling experience by grounding our narrative and our problems in climate change, while creating within-game actions that were more discretely comprehensible and more developmentally appropriate.

The strands of informal science education provided us with some guidance on how to think about problems. The six strands of informal science would have informal science learners do the following:

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- Strand 1: Experience excitement, interest, and motivation to learn about phenomena in the natural and physical world
- Strand 2: Come to generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science
- Strand 3: Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world
- Strand 4: Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena
- Strand 5: Participate in scientific activities and learning practices with others, using scientific language and tools
- Strand 6: Think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science (NRC, 2009, p. 4)

Because so many of these strands involve actually participating in scientific activities and approaching professionalization, it appeared that following Carrano's suggestion would work. We would build a community presented with compelling problems that they could solve using thinking patterns, tools, language, and so forth consistent with scientific practice. This would be driven by (but not be limited to) inductive probing and hypothesis testing. Our narrative would be set to create problems that required careful thinking and the understanding of complex problems, and each of those problems would build on one another and follow in a reasonable manner.

For instance, in the game's first challenge, we provided no clear path forward. Students noticed the codes we had placed in the video we showed, perceived them as codes, searched online for solutions and tools to break the codes, and then organized the ninety-nine separate code fragments players could discover into the single message from Jasper and Project Phoenix. One player wrote, "I thought I was going to do science, not breaking codes," and we were able to reframe the situation—this sort of inductive process *is* scientific thinking.

The subsequent challenges, in which players collected data, presented it to their "futuristic" correspondents, and discovered that they had a real communication problem due to issues with units and location also had to solve a fundamental practical problem. This communication problem touches on central scientific institutional questions in a way that enables

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players to interrogate and understand why unit systems and coordinate systems are important. Units are frequently presented as a demanding task that must be arbitrarily done, but the ability to precisely communicate information is something that practicing scientists crave out of necessity. The nature of the problem in this game induces an authentic craving that most middle school science labs fail to do.

Finally, with a healthy community developed by the fourth week challenge of helping the Project Phoenix scientists decide what tests to run to ascertain what event caused global cooling and disaster, we were able to help players build informal hypotheses to test. First, they had to work from their own knowledge and from research to determine what sorts of events cause widespread cooling. Discovering potential causes like supervulcanism, asteroid crashes, and the wandering of magnetic poles was exciting, but it also led to further questions. What evidence could Jasper and his colleagues look for in the future? What tests should they run? While players may not have precisely developed experiments to run, they nevertheless had to think carefully about the problem. In the instance of the ultimately correct hypothesis, for instance, players searched for all the existing craters on the planet and provided the coordinates so that current craters could be ruled out in a global search. They also extensively researched the detritus and material that would be found at different types of collisions so that the community could learn as much as possible about the asteroid strike should one be found.

It is important to note that, in each of these situations, we did not let the players drift in the wilderness. The field of problem-based learning is certainly an inspiration for our work in *Vanished*, providing a framework for how to think of engaged learning that situates factual content in the processes, disciplinary lenses, and contexts where that knowledge would be used. In a response to a critique of discovery learning approaches (particularly because of the tremendous cognitive load involved), researchers involved in problem-based learning and inquiry learning assert that by working through problems, learners can develop "content knowledge, epistemic practices, and soft skills such as collaboration and self-directed learning," and that these approaches are in fact heavily structured with three types of scaffolding (Hmelo-Silver et al., 2007, p. 99). The scaffolds discussed are those that make disciplinary thinking and strategies explicit, those that embed expert guidance, and those that structure tasks to reduce

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cognitive load (Hmelo-Silver et al., 2007). *Vanished* was able to use each of these types of scaffolding, in one instance or another, to reduce the cognitive load of any single problem, and to model good problem-solving skills to players. The game's staff of undergraduates was the first level of intervention. They helped players develop hypotheses (and steered them away from weak hypotheses, like an apocalypse caused by the end of the Mayan calendar); contextualize evidence and problems; and otherwise strategize explicitly. In the excerpt below, you can find a moderator scaffolding an interaction, but also players modeling and expecting professional practices from one another.

Player 1: Maybe they ran out of coal deposits and oil deposits to make fuel from? We could give Project Phoenix the coordinates of the largest present-day reserves and have them investigate how much oil and coal is left. I don't have time to do any research on this right now, but I think it's an idea worth investigating further.

Player 2: I think it's a good idea.

Moderator: That is an excellent idea! so where today's major oil reserves located?

Player 1: Well, so far I've found the CIA's official ranking of oil reserves by country, but I haven't found any exact coordinates for oil reserves. The official ranking is at the following link: World Oil Reserves [World Oil Reserves was hyperlinked to the CIA World Factbook, now found at https://www.cia.gov/library/publications/the-world-factbook/rankorder/2244rank.html]

Player 3: i know right dude! btw [Player 1 username] thts a cute name too:)

Player 4: I think the Middle East (Kuwait, maybe Qatar), and the Gulf Coast, and Alaska.

Player 5: Well based on many news reports and such i would say most of them are located in Asia in places such as …:

1. Iraq
2. Afganistan
3. Pakistan

and etc. so basically we are battling the countries with the most oil preserves so the US can gain control of them?

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Player 6: This is a very good theory too, and we could see when the last bit of oil or coal was taken out of the reserves.

Player 7: Well [Player 6 username], I have this online "clock" that tells a lot of different things and on it is a oil reserves countdown and right now it is at about 38 years left.

Player 8: yeah, well we thought oil would run out about now a long time ago, so i think that estimates are too small. And besides, if we start to use less, that would increase the time.

Player 5: Wow that is really cool [Player 7 username] where did you find it maybe more of us could purchase that type of clock unless its rarely valuble and it sounds like it is!

Smithsonian scientists were also available to provide expert guidance in times of explicit need, via a moderated video chat. Conrad Labandeira, an expert in mass extinctions, was able to help the player community make sense of divergent data and learn how to make sense of speciation. Liz Cottrell, who studies volcanoes, was able to help the community understand how volcanic activity could cause mass extinctions, and she provided possible tools for investigating the future. Finally, when it came time to study the remains of the settlements of the future, Kari Bruwelheide shared her knowledge of forensic anthropology and helped students make sense of their findings. Importantly, these scientists were not just experts, but experts with an educational mission. They treated the players as colleagues, refrained from speaking down to them, and were able to scaffold the search for answers when it was called for, as opposed to simply providing answers in all contexts.

In these ways, we believe we provided players with problems that felt authentic to them, connecting them to the pressing issue of climate change while creating a succession of activities that logically followed one after another. We were able to situate their work in a context where the skills they would be using and developing were relevant to the actual professional practice of science. And we were able to situate them as scientists socially while providing a great deal of mentorship and help from MIT students and from professional scientists from the Smithsonian. Each of these, we believe, created an environment in which players could develop an emotional attachment to, skills in, identification with, and fondness for science.

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Collective Intelligence, Citizen Science, and More!

The Principle of Social Design for Learning
Almost all learning is highly social, because knowledge may be said to be social—symbols, ideas, and knowledge are all given meaning and weight by the context in which they are operating. Further, learning in a group context can provide greater resources for learning than any given learner may have on his or her own.

When applied	*When not applied*
Respecting the social nature of knowledge and the potential benefit of shared tasks such as problem solving may have tremendous benefit for learners. Although new problems may arise, like players benefiting from the work of others without contribution, these are likely outweighed by the benefits of learners formalizing and explaining their thoughts as well as developing collaborative capacity and skill.	The principal danger of recognizing the social nature of knowledge is maintaining a myopic view of content, failing to see where your students may have their own misconceptions or perspectives that require a more flexible path to understanding. Further, approaches that focus solely on the individual miss opportunities to practice the collaborative skills students will need in contemporary workplaces.

We were tremendously inspired by the socially engaged nature of the ARG. Having players who collectively addressed complex challenges seemed like a tremendous opportunity to prepare young people for an important aspect of the twenty-first-century working world, developing collaborative skills and a sense for how to tackle challenges too large for any individual to address. These activities would require some guidance, but we largely found our players to be tremendously capable.

The capacity of large groups to solve complicated or complex problems has been called "collective intelligence." We were enormously inspired by researcher and designer Jane McGonigal's careful catalog of the ways in which the design team for 4th Wall's *i love bees* required and addressed player collaborations (McGonigal, 2008). One key collaboration was performing the investigations necessary to turn a growing list of seemingly random strings of numbers into the dates and locations when and where

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220 pay phones would ring and deliver exclusive audio content to whoever answered. Players of *i love bees* were also skilled archivists and computer scientists, noticing some pseudocode that the game's designers developed as a means of communicating that the game's narrator was an artificial intelligence. These two challenges required players to produce a wide array of hypotheses, to imaginatively develop or investigate these hypotheses, and to resourcefully, creatively chase down the information and answers they sought. For instance, the players working to decode what ultimately were payphone coordinates pursued a wide array of possible interpretations. The players established separate threads for literal (*we just need to go to these places*), relative (*what's at these coordinates?*), and numerical hypotheses about the meaning of the numerical strings.

Additionally, we were inspired by researchers studying the larger context around game-play activities, or what James Paul Gee calls "The Big 'G' Game." Addressing the idea of "affinity spaces," researchers were just beginning to study how players would investigate game systems together in online forums while also developing relationships with social significance through their participation in shared activity. Members of these affinity spaces may have been less likely to share personal information unless it was germane to a given topic, but communications were frequently respectful and well organized, presumably because of the deep shared interest in effectively uncovering how to improve their game play.

In *Vanished*, our players solved problems in which the data were widely distributed, puzzles that required a great deal of detective work and problem solving, and challenges that required simply being geographically distributed. The puzzle described above, in which a coded message was split into ninety-nine unique fragments, required players to imagine what their text strings might be, to infer that they were codes, and then to assemble the decoded fragments into a coherent message. Other challenges had them collecting temperature and creature data from their zip code, or going to nearby Smithsonian affiliate museums (or encouraging cousins, friends, etc., to go if no players reported being nearby). Finally, a great deal of players' work came from simply coordinating activity, encouraging one another, and crowdsourcing knowledge around various in-game puzzles and challenges. They worked diligently to communicate with one another and share knowledge and practices to solve the game's mysteries.

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Finally, we drew inspiration from Albert Bandura's notion of social cognition (Bandura, 1986), the idea that young people develop a sense of self-regulation and self-efficacy from the models provided by those around them. If good behavior is modeled and reinforced by all members of a system, the behavior becomes mutually constitutive and drives what Bandura calls "reciprocal determinism." We wished to conduct good community hygiene to keep the dialogue between players positive and productive, within parameters. We wanted students to get to know one another and conduct some amount of friendly discourse while not turning the game into a wildly off-topic discussion space.

We tried to make our community much like the communities our players would encounter in other places online. Players had simple profiles as their principal means of communicating their identities and primarily interacted through posts on a shared forum. Of course, as our players were between the ages of ten and fourteen, we had to work to protect them from themselves and from others. This is in part just good practice, taking good care of your young players online, but doing so is also legislated through COPPA, or the Child Online Privacy and Protection Act.

While the COPPA regulations are carefully elaborated in many locations, for our purposes, the laws cover what content is appropriate content for a website for children under thirteen, how much information children are allowed to share on the site, and what is done with that information. We sought expertise in terms of how to oversee our data and worked closely with MIT's internal review board (the Committee on the Use of Humans as Experimental Subjects, or COUHES) to develop our plan. We did engage players from all fifty states and Puerto Rico as well as a roughly equal proportion of boys and girls (51%:48%). Players were from zip codes with household incomes slightly higher than comparable to the US average at the time. They could see only what state other players were from, though, as well as game-related information.

We made the challenges of monitoring a community of ten- to fourteen-year-olds into benefits. Every post in the forum was checked by our undergraduate community members for appropriateness and for identifying content like a player giving out his or her full name, address, or other contact information like an email address or phone number. We had some concerns that players would be discouraged by not seeing their thoughts

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posted immediately, but we were able to keep the time to filter extremely low. The players seemed happy with the arrangement, and we had to ask only one player to modify behavior. The resulting community was friendly, chatty, and productive without becoming the lowest common denominator basement that many Internet comments sections often become. We also chose a diverse group of undergraduate mentors to moderate the forums, people with a history of working with youth, old enough to be aspirational but young enough to be relatable, and we did weekly video updates in which the mentors would respond directly to players to build the relationship.

Our players were interested in our mentors and had many interactions with them, but they were even more interested in one another and, on average, spent 12 percent of their time looking at one another's user profiles. These user profiles were sparse, though, to protect players, but it's an indicator that providing players with ways to get to know one another within the bounds of COPPA is valuable.

This productive community was of course supercharged when given the opportunity to communicate with Smithsonian scientists. Our moderated chats, conducted by Learning Time, Inc., allowed our students to participate in live dialogue with professional scientists conducting extremely exciting research (see figure 4.7). The scientists were all capable educators, which is one of the expected roles of a scientist conducting research at the Smithsonian, so they were wonderful in the ways they addressed the players' questions and interests, maintaining the game's fiction and never merely conveying an answer, but rather leading the players to their own "aha!" moments. The effect of welcoming players into the community of practice of scientific researchers, situating the players as novice colleagues rather than as merely an audience of children, was incalculable. In this way, the players' involvement in the discovery of new knowledge and in the process of inquiry was given serious import. The players acknowledged this in an end-of-game survey:

> The Web Conferences. I don't know about everyone else, but I had always wondered what exactly it means to be a 'scientist'.

> I must say that my favorite thing about Vanished was the web conferences! It gave us all a chance to speak with amazing scientists who work in very diverse fields of science.

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you should definatly get some more video conferences they were a fun and easy way to learn about so much!!!!!

I didn't actually expect these to be very fun but I think they were my favorite part of the entire game.

Importantly, there is one chief social design tool that we did not use—role playing and roles to drive identity and focus tasks. The chief identity work that we hoped to do was to have students see themselves as at least comfortable with science and the idea of being a scientist, but ideally, eagerly seeing themselves as scientists in their adult lives. The creation of roles in a game typically divides game tasks into coherent jobs—many fantasy role-playing games adopt "tank," "damage-dealing," and "healer" roles. Roles can even be arranged in opposition to one another, as are the "corporation" and "runner" roles in the card game *Android: Netrunner*. It was important to us that our players have a great deal of flexibility in how they position themselves toward other players and the activities in the game. Games with roles are generally ongoing and enable players to try out different roles and other social flavorings to find ones they are comfortable with. Because of our game's short timeline, we were reluctant to overspecify

The Principle of Multiple Pathways and Freedom of Effort
Although little evidence to date supports the idea of learning styles, evidence does suggest that children vary their efforts in playful situations as their goals change. Similarly, evidence shows that good learning is voluntary and has clear goals that are meaningful to the learner.

When applied	*When not applied*
Learning activities that have multiple pathways to knowledge and learning designed into them are simply more accessible to students. Further, opportunities for learners to modulate their effort allow them, within bounds, to develop a more intrinsic relationship to knowledge, free from the extrinsic pressures.	Uniform, one-size-fits-all approaches to education can be effective for a great number of students but may fail to recognize and to provide aid to the students that need it the most. Many education projects in systems already provide accommodation to learners with disabilities and differences. Less common are educational ventures that have opportunities to sometimes modulate effort.

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how people could contribute. In fact, ARGs tend to benefit from an "all hands on deck" mentality, where people contribute as much as they can, wherever they can and want to. We still believe this to be a compelling dimension of the format. In informal education spaces, it is not necessary for every learner to perform every activity in the same way—in fact, there is a benefit from collaborative activities in which learners can model activities they are good at for their peers, and in which students develop skills around finding roles for themselves in groups. We wanted to capitalize on this opportunity while scaffolding the ways in which players might contribute in *Vanished*.

Squaring the ARG Pyramid

In ARGs like *The Beast* or *i love bees*, the developers at 4th Wall Entertainment noticed a phenomenon in which a small number of players would diligently work to solve just about every problem in the game or contribute meaningfully to the generation of game-related content. Another, larger group made smaller, perhaps less consistent contributions to the game, and a final, much larger group contributed in minor ways, largely watching the action as it occurred. The 4th Wall developers call this the ARG pyramid (see figure 4.1).

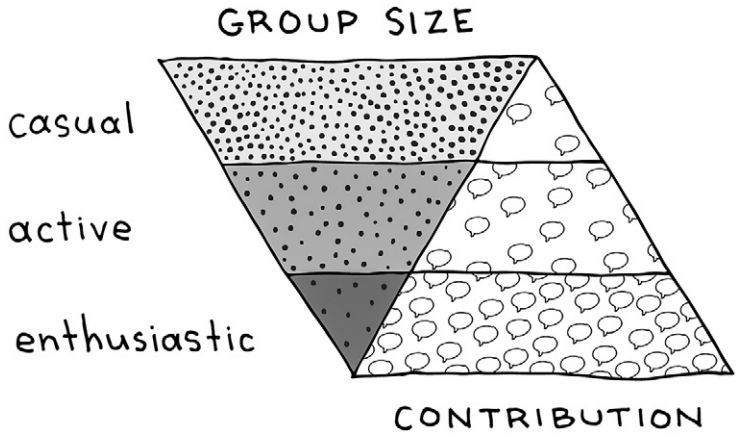

Figure 4.1
The ARG pyramid, showing varied proportions of players by participation and contribution

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Similarly, online collaborative spaces like *Wikipedia* have developed their own name for this pattern, calling it the 90/9/1 problem, meaning that 1 percent of their users are heavy editors and contributors, 9 percent are moderate editors and contributors, and 90 percent simply use the site for reference. Jane McGonigal's *EVOKE* ARG, conducted with the World Bank, released figures that revealed an 88/10/2 split. *Vanished*, however, had a 69/25/6 split. Of course, it can be challenging to standardize what it means to be a "heavy," "moderate," or "casual" user across very different activities like this, but we believe that we were able to "square the ARG pyramid" a bit by designing multiple pathways for players to contribute. Players of *Vanished* could not only select how they wanted to contribute, but could contribute in different ways over time.

Our inspiration for this model was the same one that drove Osterweil's freedom of effort principle (see chapter 2). Scholars of play Peter and Iona Opie (1969), studying children's street games in 1960s England, noticed that most children, when playing a game like tag, will be actively running away from other players, or even just running, and then will stop and hang back for a while. Perhaps out of breath, perhaps just observing the scene or checking in with themselves, these players would suddenly find themselves at the periphery, possibly rejoining the fray, or possibly remaining at the edges for the rest of the game. *Vanished*'s diverse array of activities was designed specifically to provide players the opportunity to decide how they wanted to contribute to the community each time they logged in.

We also drew inspiration from Gee's "multiple routes principle." Gee writes that in good games, "there are multiple ways to make progress or move ahead. This allows learners to make choices, rely on their own strengths and styles of learning and problem solving, while also exploring alternative styles" (2003, p. 105). By affording players a certain level of autonomy and choice, we believed that players could coconstruct their preferred experience with us. It is important that in an informal learning space, learners be accorded such leeway.

As discussed above, players had several opportunities to participate in the central mystery, through active problem solving, performing organizational activities, or simply lurking. In this section, we show other pathways within the game that players could use to contribute to the group's collective progression through *Vanished*. We feel that all these pathways are not only valid, but incredibly valuable ways to contribute to the community.

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One of our major alternative pathways in the game was to play small Flash games that were released each week in conjunction with dispatches from Jasper and Project Phoenix. The ostensible fiction was that many of these games existed for the original *MIT-Smithsonian Science Game*, so undergraduate support staff members were releasing things from the archive as they saw fit. In the first week, we provided players with the text assembly tool Amalga, which was essentially a "refrigerator magnet poetry" tool that allowed players to load in their fragments and reorganize them in different ways (figure 4.2).

Although the tool was not a game explicitly, we tried to ensure that players would have an easy way to complete the hardest part of the first challenge. It was important to us that the community feel sufficiently challenged by that first puzzle, but that they also felt entirely capable of solving it and that they experienced success.

In the following week, when we rolled out *Nate's Swamp Hunt*, we hoped that the game's central mechanic of converting units would help players think about the importance of conversion, and perhaps give them the opportunity to practice that skill. The game's protagonist, controlled by the players, has received directions to a fortune buried in the swamp by

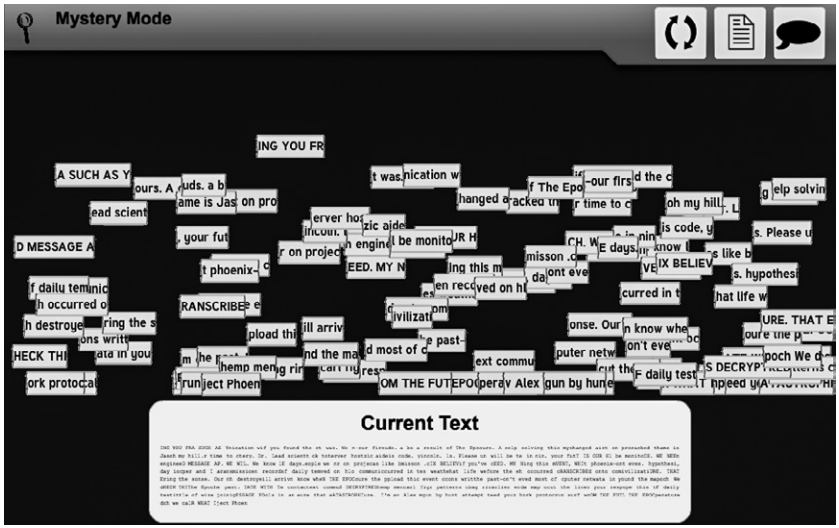

Figure 4.2
The Amalga tool, used to assemble player text fragments

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an eccentric and now-deceased uncle. Uncle Nate provided directions in unconventional measures like "trombones" and "snakes," but the players have only a group of uniform-length boards with which to cross a perilous swamp. By carefully converting from snakes to boards and through efficient use of boards, players could uncover a series of treasures hidden by Uncle Nate (see figure 4.3).

After releasing *Nate's Swamp Hunt*, however, the game's staff discovered to their (mock) surprise that a seemingly rogue artificial intelligence, escaped from Project Phoenix, had ensconced itself in the game. This AI, who called herself Lovelace (see figure 4.6 for an artist's rendering), created a reward system in the game, allowing players to gain points for playing *Nate's Swamp Hunt*, which could be used to unlock documents that she had taken from the Project Phoenix databases. These documents would prove to be mysterious artifacts of the human future.

In the Education Arcade, we place a high value on providing players with means of participating in our games because of their *intrinsic* interest. In other words, it is important that players should want to participate in our games because they are fun and compelling in and of themselves, not because they want a certain score, a badge, an achievement, or some

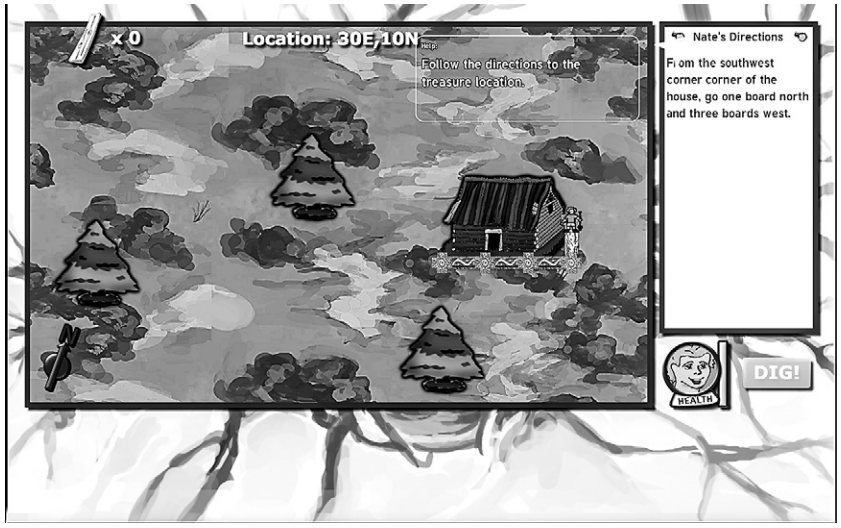
x 0
Location: 30E,10N
Help
Follow the directions to the treasure location.
Nate's Directions
From the southwest corner corner of the house, go one board north and three boards west.
HEALTH
DIG!

Figure 4.3
Nate's Swamp Hunt, a game involving unconventional units of measure

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other kind of *extrinsic* reward. Research in the field indicates that extrinsic rewards tend to lead people to value the rewards, as opposed to valuing the activity that has been incentivized. These strong commitments drove us to make Lovelace a somewhat hostile antagonist, calling attention to her creation of a pool of hidden documents, only unlocked by playing games that had no connection to the documents themselves. We felt that the compromise, and winkingly including the players in the joke, enabled us to provide fun, intrinsically interesting games within the larger structure of *Vanished* while doling out content at a slow pace and, most importantly, allowing players to find a way into the game or to throttle their efforts down if they wanted to.

One other Flash game, released in week four, called *Astrodefense*, asked players to defend a futuristic space colony from incoming asteroids, both by carefully managing the colony's resources and by developing sufficient technological capability to defend against larger asteroids (figure 4.4). The game included a great deal of information about the types of asteroids and foreign bodies that might approach from space, and about how the weaponry to defend the earth might develop. In this week, players had to think

Figure 4.4
Defending your space colony in *Astrodefense*

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about why it might be challenging to defend against an asteroid strike in the not-too-distant future.

Finally, in the last Flash game, players got the opportunity to explore the future from which Project Phoenix was calling with the control of rovers not dissimilar to the rovers NASA has sent to explore Mars. Unlike the previous Flash games, players were now, in game, connecting to the world of Project Phoenix. The application to use the rovers was essentially a *Zork*-style text adventure with a graphical interface. Players had to manage resources to cover the maps, scan for the archaeological remains of buildings, and dig for artifacts (figure 4.5). The story of humankind's slow descent into nineteenth-century technology was chronicled in the structures, artifacts, and documents uncovered in this process.

Lovelace would, of course, also give out credits for other activities in the game, like uploading data for various challenges and visiting the affiliate museums. These tasks were legitimate parts of the larger inquiry process of the game, but they manifested a couple of approaches to engaging players who might have been be lurking more deeply. The first approach was through credits, but the second made them potential heroes by dint of their geographic location. In the first data challenge, uploading temperature and

Figure 4.5
The rover that players used to explore the remains of settlements in the United States

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speciation data to the system, enabled players to provide the special local data that they and few other players probably had access to. Once the activities in affiliate museums kicked off, players were provided with an opportunity to give real aid to the *Vanished* community by visiting a museum (as in figure 4.8) on the weekend to, for instance, participate in a demonstration about keystone species. One player drove from Montana to Colorado to participate in a museum event.

Even though 70 percent of players engaged in the Flash games and only 7 percent were able to attend the online conferences with scientists, some players emerged only to connect with the Smithsonian scientists, or only to engage with Lovelace in her rare appearances. They were all a part of the experience and, we believe, came away from the game more predisposed to engage with scientific practice than they would have been prior to the game. It's difficult to prove this, of course, but we are hoping to conduct a follow-up study now that our players are in their late teens. Not all players did the same things, but they came and hung around a while—we hope that means something.

Figure 4.6
An artist's rendering of Lovelace

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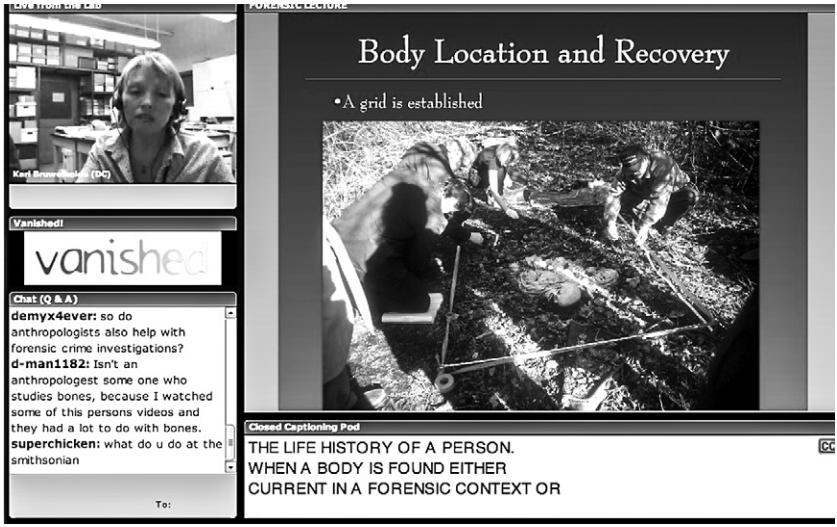
Body Location and Recovery
•A grid is established
Vanished!
vanished
Chat (Q & A)
demyx4ever: so do anthropologists also help with forensic crime investigations?
d-man1182: Isn't an anthropologest some one who studies bones, because I watched some of this persons videos and they had a lot to do with bones.
superchicken: what do u do at the smithsonian
To:
Closed Captioning Pod
THE LIFE HISTORY OF A PERSON.
WHEN A BODY IS FOUND EITHER
CURRENT IN A FORENSIC CONTEXT OR

Figure 4.7
A screen capture of the video chat with Kari Bruwelheide of the Smithsonian

Figure 4.8
A child examining artifacts at a Smithsonian museum

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Make-Believe Scientists

The Principle of Narrative and Imaginative Cocreation
Good narratives often encourage constructive make-believe behaviors in players. Players who are pretending have opportunities to find new meaning in concepts and skills and to try on potentially generative new identities.

When applied	*When not applied*
Resonant games that allow students to make believe and to cocreate can provide opportunities to project their identity into new roles and consider new ideas with a flexibility and curiosity that may not be available in more straightforward instructional settings. Compelling make-believe experiences require art and science to be as effective as possible.	Great learning can occur without make believe or cocreation. Nevertheless, learning is frequently better with a deep investment on the part of the learner. With a deep investment, learners will persist, consider new perspectives, and even celebrate the tasks and knowledge they are engaged with.

This idea of "meaning something to someone" is crucial to understanding resonant games. As mentioned in chapter 2, games are designed experiences. Games cannot be one-size-fits-all, but should be directed at creating experiences that can be meaningful to many people in many different but important ways. Traditional storytelling tools like narrative and make believe can be crucial to pulling people into your experience and helping them make sense of their experiences. Narratives structure events sequentially and provide a framework to understand how ideas and experiences might build on one another. Further, make believe allows players to be more receptive to new ideas and more awake to different possibilities and experiences (Deterding, 2016). We developed the narrative for *Vanished* in part inspired by the narratives that had so effectively worked for games like *The Beast* and *i love bees*. We also developed our narrative to inspire players to connect to our activities and to climate change. We intended our narrative to organize a series of events, to build suspense, and to deliver surprise and catharsis for our players, while helping them make sense of their activities in a fictional but still situated environment.

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For *Vanished*, we felt it was important to start with the larger narrative. We had a seemingly large problem, which is that climate change is a difficult issue to involve people in—the timescale is very long, the negative consequences can feel numerically quite small (i.e., a single degree increase in average global temperature can be consequential, and ten meters of sea-level rise could sink several coastal cities and islands), and consequences such as species extinction can be entirely invisible. Human-computer interaction legend Brenda Laurel, in discussing her ideas about Gaian Interaction Design, invokes the idea of climate change as a "hyperobject," a phenomenon "that 'stretch[es] our ideas of time and space' beyond human scale" (Laurel, 2011, p. 38). In this paper, Laurel discusses *Vanished* in particular, noting:

> In *the Poetics*, Aristotle identifies one of the central distinguishing characteristics of drama as its compression of time in the selection and arrangement of incidents. That's how the generation-length action of *the Oresteia*, for example, was presented as three plays, each of which could be taken in within the attention span of an audience. Dramatic compression could also be used to visualize climate change in a way that could be grasped by an audience. The folks on the MIT team did the next best thing: They generated a future scenario in which aliens studying Earth couldn't understand what had happened to it because all the data from previous civilizations had been lost. The mystery was to discover what had caused that erasure. By scoping into the future and exercising dramatic compression, the MIT team was able to indirectly represent the hyperobject. (p. 44)

This dramatic compression was essential, allowing us to bring the message of climate change's implications home to our players. But this wasn't the only time compression we employed. We needed to keep our challenges fresh each week, while ensuring a steady build to the climactic reveal that Jasper and Project Phoenix were aliens and that Earth had been depopulated of humans. It was important that the challenges drive the narrative, not the inverse. Narrative in video games can often take the form of a cut scene, taking you out of the action. For us, it was important that the challenges have a narrative reason to occur, and that the results of the challenge feed back into the narrative.

We also had to manage our own workload and find a way to release the game in a way that would allow us to help our young players manage their own time. More traditional ARGs could be round-the-clock phenomena, posting information at any hour, creating a player base that connects to the game constantly, ensuring that they don't miss anything. We decided

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early on that we should release the major content dumps and puzzles of our game in serial fashion instead, preparing a set amount of content for each week. Game staff were still watching the game in real time. Using the vague challenges of time travel as our rationale, we assured the player base that it was important for communication with Project Phoenix to occur once a week, giving them a dedicated time to give most of their attention, and giving our small team time to react to whatever players threw our way. Serialization had a benefit beyond the logistical, however.

The film serials of the 1930s to mid-1950s were frequently science-fiction or action adventure stories that contained exciting plots designed to entertain young children. Most episodes in a serial ended with a cliff-hanger, a moment of suspense that pulled people into the experience, thrilling them and keeping their interest until the next episode. These stories were produced cheaply and inexpensively, so thrills were frequently the focus—characterization and internal logical consistency were not often important. Our focus on STEM education meant that internal consistency and logic were much more important to us, but we believe we benefited from the "rising action into a cliffhanger" structure, as well as something that we can hypothesize about—capturing the player's imagination and play between episodes. Film scholar Scott Higgins, while cautioning that there are few records to this effect, points to some evidence of how serials would shape the play of children between episodes. He quotes from early twentieth-century sociologist Alice Miller Mitchell's *Children and the Movies*: "The movie has become a new back yard for the after-school-hours child. … Not only is it a better and a more interesting playground to the child, but it makes more attractive to him his own playland, for when he returns from the movie to his 'back-yard' he has new ideas of what to play and how to play it. He and his little companions congregate and begin to re-enact the film they have seen" (Mitchell 1929, pp. 75-76). Higgins writes, "In Mitchell's estimation, motion pictures were both a replacement for the traditional play space, and a force for reconfiguring that space. … The sound serial's formula of regular combat embedded in an overarching mystery would seem tailored to children's preferences, perhaps because they occupy story and play's shared territory of contest and the puzzle (see Murray 2004)" (Higgins, 2014, p. 107). Although *Vanished* had only hints of violence at the very end, we absolutely pulled our players into weekly contests and puzzling with the game's systems and models of the

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world, embedded in the time-compressed narrative about the hyperobject of climate change. Thus, where early sociologists were concerned about the "emotional possession" (Blumer, 1933) that these patterns of consumption aroused in young people, we believe that we were able to draw in both their emotions and their intellect to engage deeply with the work of being a scientific community because unlike the sound serials, *Vanished* was interactive. The story could not move forward without engagement from the players. In the time between the weekly transmissions and puzzles, there was discussion about what would happen next. And at the beginning of every chapter, we had gifted illustrators draw "the story so far" cartoons, which functioned similarly to the "previously on" edited clips that catch up or remind audiences of past episodes at the beginning of contemporary serialized TV shows (figure 4.9).

Higgins does discuss ARGs in his paper, but he sees them as the playground to act out contemporary narratives with rich characterization like *Lost*. *Vanished*, as a serialized ARG, was able to ritualize the players' engagement and bring the scientific, investigatory imagination to bear in

THE STORY SO FAR...
WE'VE BEEN SENDING TEMPERATURE TO PROJECT PHOENIX RESEARCHERS WHO CONTACTED US FROM THE FUTURE.
UNFORTUNATELY THEY USE DIFFERENT MEASUREMENT SYSTEMS FOR TEMPERATURE AND DISTANCE.
WE'VE BEEN HEARING FROM LOVELACE, WHO INTRODUCED ITSELF AS AN AI TRYING TO FIGURE OUT WHAT CATASTROPHE WILL OCCUR IN THE FUTURE.
WHAT CAUSED THE CATASTROPHE?
VOLCANO? GLOBAL WARMING? PROJECT PHOENIX?
LOVELACE HAS ALSO RELEASED PAGES FROM THE JOURNAL OF SOMEONE NAMED "DOC."
DOC'S JOURNAL
THESE HAVE LED US TO VISIT CERTAIN MUSEUMS TO INVESTIGATE.
?????
EVERYONE WORKED TOGETHER TO FIGURE OUT HOW TO CALIBRATE OUR DIFFERENT SYSTEMS OF MEASUREMENT.
LOVELACE HAS ALSO RELEASED DOCUMENTS FROM THE FUTURE.
WE COLLECTED DATA ABOUT NATIVE ANIMAL SPECIES AT THEIR REQUEST
WE FOUND A STRANGE ATTACHMENT AT THE END OF PROJECT PHOENIX'S LAST COMMUNICATION WITH US.
WHAT DOES PROJECT PHOENIX WANT TO KNOW ABOUT ANIMALS?
WHAT IS LOVELACE'S CONNECTION TO PROJECT PHOENIX?

Figure 4.9
"The story so far" image reminded players of past game action

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their in-between play. While we know that players would sometimes hang around in the forums between dispatches, we think their imaginations were also engaged between episodes. In recent years, we have seen online communities spring up to discuss what will happen next on a suspenseful show such as *Lost* or *Breaking Bad*, a developed universe for fan theories and speculation, and we saw the same behavior on our forums.

Player 1: I agree that all those are logically ideas, but did you ever consider the fact of a World war 3 or a real cold war.

Player 2: That could actually be the case! After all, there is lots of armor and weapons at Huckleberry and lots of skeletons and bones that were wounded by stabbing or shooting or such. Also, maybe they just used up so much technology in the war that they didn't have any left and they didn't have the supplies to remake it! Or maybe part of the peace treaty that ended the war was something like "We won't use advanced technology as long as you don't as to prevent another horrible war like this one from ever occurring."

As important as the narrative structure was, *Vanished* was nothing without the imaginative play, or make believe, of our players. Scholar Sebastian Deterding sums up the benefits of make believe:

> Make-believe can stoke curiosity and arousal through surprising theming and suspenseful narrative. It can facilitate understanding and learning through organizing knowledge in experientially grounded metaphor and story. It can make us like and care about faceless systems as if they were real people, and lend tasks and goals relevance by linking them to values and (fictional) people we care about. It can open and motivate us to explore new identities, behaviors and experiences that lie outside our normal social roles. It can absorb and focus our attention, cognition, and emotion, making us more susceptible to persuasion. It can allow us to express and then follow in the footsteps of our own better selves, and enable us to see the world through the eyes of others. (2016, p. 117)

Our players were heavily invested in our characters and our story, and so they performed a great deal of truly challenging work. Even if players were largely playing the Flash games, they still had to perform challenging tasks, and they saw the game as worthy of their time and efforts. Our players, we believe, saw themselves as protagonists and as scientists. And we rewarded their make believe by playing with them in a manner typical of ARGs. We listened to what the players were saying and doing and did all we could to play with them. For instance, Lovelace was a character invention

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that solved storytelling and game design problems for us, but she became a fan favorite because of the mysterious and playful actions she engaged in with the player base (thanks to her puppet master, project manager and codesigner Caitlin Feeley). Lovelace's story and her role within the universe of *Vanished* expanded over time, and when Lovelace was freed at the end of her work, like Ariel in *The Tempest*, there was some debate among the players about the ethical thing to do with an AI—should they teach it how to be human, "set it free"? While the players developed a distrust of Jasper and Project Phoenix as their answers about the future of humanity became more evasive, the players' interest in a future that was possibly their own deepened tremendously, and when all was revealed in the end, the players were very understanding and forgiving of the unreliable guide we had created for them.

Perhaps the best indicator of our players' investment in our story was that, about halfway through the game, a technically skilled player announced in the forums that he had found a way to hack into the repository of documents that Lovelace was playfully/cruelly doling out at a slow drip. He did not, as you might expect, simply link to a repository of game-breaking information, but instead he asked what the game runners would prefer, and what the community would prefer. In short order, he received a clear message from his fellow players: "please don't spoil things for us—we're having too much fun!" (We gave him some additional credits for his ingenuity and kindness.) In the same way that parents and children in a family may, for a year or so, talk about Santa Claus as if he's real, even though the children have their suspicions or knowledge to the contrary, we found a sweet spot where children and adults could have some fun pretending together, for a time, that things more fantastic than reality were occurring, and we inspired them to do some very challenging work to keep up the illusion. This was a shared, temporary center of focus, as in Salen and Zimmerman's (2003) interpretation of Huizinga's (1930) concept of the magic circle, discussed in the previous chapter.

We Saved the World—Now What?

On May 22, 2011, we concluded the game. Players received a message from Lovelace, reporting back from the alternate future just as the scientists from Project Phoenix were arriving at the now intact Earth in the future (see figures 4.10 and 4.11).

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Figure 4.10
The final image of *Vanished,* showing players the celebratory moment of contact with Project Phoenix

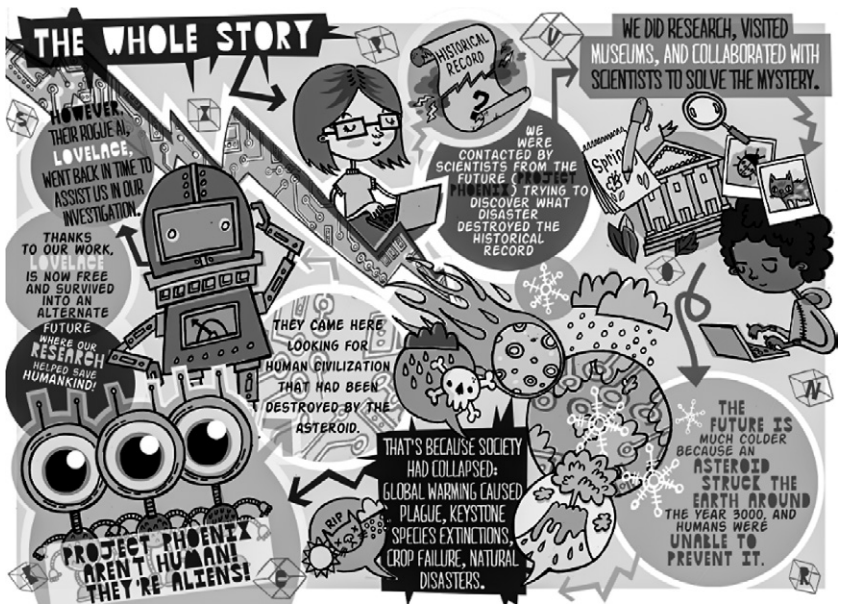
THE WHOLE STORY
HISTORICAL RECORD
?
WE DID RESEARCH, VISITED MUSEUMS, AND COLLABORATED WITH SCIENTISTS TO SOLVE THE MYSTERY.
WE WERE CONTACTED BY SCIENTISTS FROM THE FUTURE (THEY'RE) TRYING TO DISCOVER WHAT DISASTER DESTROYED THE HISTORICAL RECORD
HOWEVER, THEIR ROGUE AI, LOVELACE, WENT BACK IN TIME TO ASSIST US IN OUR INVESTIGATION.
THANKS TO OUR WORK, LOVELACE IS NOW FREE AND SURVIVED INTO AN ALTERNATE FUTURE WHERE OUR RESEARCH HELPED SAVE HUMANKIND!
THEY CAME HERE LOOKING FOR HUMAN CIVILIZATION THAT HAD BEEN DESTROYED BY THE ASTEROID.
THAT'S BECAUSE SOCIETY HAD COLLAPSED: GLOBAL WARMING CAUSED PLAGUE, KEYSTONE SPECIES EXTINCTIONS, CROP FAILURE, NATURAL DISASTERS.
RIP
THE FUTURE IS MUCH COLDER BECAUSE AN ASTEROID STRUCK THE EARTH AROUND THE YEAR 3000, AND HUMANS WERE UNABLE TO PREVENT IT.
PROJECT PHOENIX AREN'T HUMAN! THEY'RE ALIENS!

Figure 4.11
The summary image from *Vanished,* celebrating all that happened

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While an evaluation conducted by educational research firm TERC (Simon et al., 2012) found that only about 670 players hung in with us into the final weeks, the players we had were overwhelmingly positive about their experience.

I completely loved Vanished! I don't know what to do with my life now that it's over. … haha, just kidding. But it seriously consumed most of my life for the 8 weeks it went on!

I believe that this investigation has definitely given us more tools and tips on how to become better scientists and has given us more methods to use when trying to discover something like this

I really feel like a future scientist now. Imagine, when we all have famous jobs at research centers across the world, someone will discover how we all as kids worked on a game.

Players went on to create fan art, to implement their own text-based role-playing games online, and to create fan sites. The players created their own mailing list to continue conducting investigations together, and they offered to conduct bake sales to fund a sequel to *Vanished*.

Just as encouraging were the contacts we had from the adults in our players' lives. One teacher of at-risk seventh graders encouraged students to sign up for the game. At the end, this teacher reached out to us, writing,

My students learned how to work together to solve problems they knew nothing about to start with. They learned how to assimilate knowledge and then apply what they had learned. They learned how science really works! I had one student … who even became very involved in cracking the codes using all sorts of different methods. Every day he would come into class thrilled to tell me what he decoded and how he did it. I overheard a few students mention that they now want to be scientists when they grow up.

This does not mean that we can rest on our laurels. Most of the players we attracted to the game were already interested in science (even if only 39 percent listed a STEM discipline as their favorite subject in school). And the attrition over the course of the game makes it challenging to advance this model as is. Our principal endeavor now is developing a model for the classroom ARG in a box, providing principles and structures to help teachers develop their own extended narrative investigations in a smaller community that is easier to scaffold for all learners. Still, there is something to be said for the development of large-scale informal games like *Vanished*

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as well. A narrative social mystery with multiple learning pathways and authentic problems in which young learners can participate in a new community for a time with others should be an option. If institutions like MIT and the Smithsonian were able to produce one such event every few years, problems like player attrition may be solved because even as the specifics of the event are unknown, the type of event it is could be known, enabling us to reach enthusiastic new players while helping us to better refine the games' various pathways and engagement models. In any event, games that combine authentic problems, clever social design, narrative, and imaginative cocreation, as well as providing multiple pathways for players, have a much greater opportunity to be resonant with young learners.

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5 Discovering the Secret World of Ysola

It is, in fact, nothing short of a miracle that the modern methods of instruction have not yet entirely strangled the holy curiosity of inquiry; for this delicate little plant, aside from stimulation, stands mainly in need of freedom. Without this it goes to wrack and ruin without fail.

—Albert Einstein

Making connections between disparate but related concepts is critical to understanding the world around us. *The Radix Endeavor*, an MMO-style game based on math and biology systems, was designed to get students recognizing and thinking about those connections. Beyond math and biology content, it aims to engage students in deep thinking and problem solving, putting them in a situation where they have no choice but to figure things out on their own. They do that by making connections within the game world, which in turn leads to connections that reach out into the world of the classroom and beyond. Engaging in the inquiry process and making these discoveries results in ideas that resonate far beyond the time spent in front of the computer.

Although it may seem counterintuitive, this kind of connective deep thinking does not commonly emerge in formal school settings. On the contrary, the sentiment in this chapter's opening quotation unfortunately endures in many classrooms today. Knowledge is imparted and procedural skills are taught, but creative, independent, and deep thinking is more rare. There are certainly pockets of good thinking going on, such as when individual teachers go out of their way to foster "curiosity of inquiry" and make space for it in their classrooms. Even the occasional school will take on the challenge of integrating "alternative" pedagogies such as constructionism or project-based learning. But the reason they are not more widespread is

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that they are just that—alternative pedagogies—in an educational system that doesn't currently value inquiry and deep thinking, at least as expressed by the measures it uses. The lack of these types of learning in practice is not because of an inability or an opposition to implementing them, but rather because of external factors such as limited time, mismatched assessments, and unsupportive stakeholders. The pockets of deep thinking that are happening and the positive response they get demonstrate a pent-up demand in teachers and students to be able to engage in inquiry learning. Resonant games, being situated, integrated, and student driven, can help create this type of learning experience—one that provides the context, motivation, and scaffolding to get students doing the hard work of thinking for themselves. One of the key ways *Radix* supports this goal is by enabling students to make connections between what they have done in the game and other experiences in the outside world. Doing this means students have to identify patterns across contexts and apply concepts in multiple ways, which is a type of thinking students are not often challenged to engage in. These connections between the game, the classroom, and the world may take a wide variety of forms.

For example, *Radix* has a stool tool which lets players examine animal feces to see what they contain. A class of biology students played the game and figured out that they could use this tool to examine glumbug droppings and understand the glumbug's role in the game's swamp ecosystem. Later in class they read articles about various ways in which scientists analyze prehistoric animal dung to learn about how creatures like woolly mammoths died out. In this instance, the game enabled them to have an authentic experience with the scientific inquiry process, while providing a foundation for a wider view of how those techniques can be applied in the real world.

As another example, students at the Museum of Natural History played the genetics quests in *Radix*, getting practice identifying inheritance patterns and understanding how a fictional plant's genotype determines its phenotype. Then in lab they had the opportunity to explore genes from another angle, learning to do DNA extraction and identify the genotypes of real plant matter they collected themselves. This gave them two different entry points to explore the ideas in genetics and compare what the game let them do with what they could do in the lab.

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Finally, a group of afterschool students used the trait examiner to discover all the creatures in the *Radix* world and catalog their traits and which varieties they found. Then as a creative extension, they were challenged to come up with their own creatures, design a variety of plausible traits, and explain why the creatures may have developed those adaptations. This activity got students to think more deeply about animals and adaptations beyond the game, bringing in prior knowledge and motivating them to do their own research. These are just a few examples of how game play in *Radix* can be tightly connected to activities outside the game to create a deeper and more long-lasting learning experience than either activity on its own.

Backing up a bit from how the *Radix* game-play experience facilitates connections and deep thinking, we should also look at how the game was designed to enable these connections, and how the implementation was designed to foster them. We started from within the game, designing an authentic, though fictional, world, populating it with rich species and characters, and providing a set of exploratory tools. Along with the game's narrative and quest tasks, these elements set the foundation of students' in-game experiences. We purposely provided opportunities to probe complex systems and independently make discoveries that, while unique to the game, were also meaningful and transferable to the real world. In addition to designing the in-game experience, though, we also worked to design the experiences surrounding the game. Classroom implementation includes a complex array of factors, such as location, timing within the curriculum, requirements, pedagogical approach, social facilitation, transfer activities, and so much more. We designed resources, implementation plans, and professional development sessions to help teachers customize an implementation that was best for their classes while supporting the core goals of the *Radix* project. Beyond the classroom, we also worked further outside the game, taking into consideration the larger ecosystem of schools and districts that the game would be functioning within. This ecosystem and the relationships within it are depicted in figure 5.1. As much as we may wish that a great game and a great teacher can make great learning, the reality is that those components exist within the larger education system, and learning experiences need to be designed to function within those constraints.

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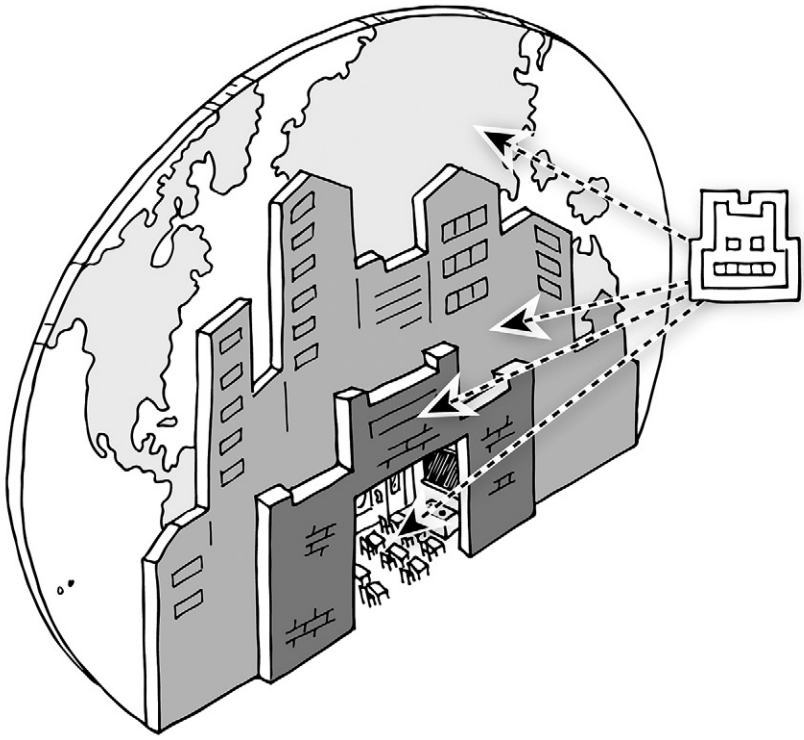

Figure 5.1
Resonant games interacting with each layer of an educational ecosystem, including the classroom, school, district, and society

To create a complex game for use within a complex ecosystem, designers will want to keep in mind several principles that apply to each realm relating to the game and implementation. These are not concrete items that can be checked off a list, but rather guiding principles that designers can use to continually check in as they build their offering and balance the various aspects. The following are the primary high-level principles that went into the *Radix* project and that can be applied to future resonant games projects:

- Designing systems for exploration
- Making curricular connections
- Creating a culture of inquiry
- Working within an educational system
- Providing professional development

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Before delving into the details and examples of these design principles, we'll first present an overview of the *Radix* world and game-play experience, along with the educational content embedded within it.

The *Radix* Project

Massively multiplayer online games (MMOs) are a genre of game that consists of open worlds that encourage exploration and experimentation. Learning in these environments often involves hypothesizing, probing, observing, reflecting, and adjusting strategies before trying again (Gee, 2003). Typically in a game of this genre, players find themselves in an unfamiliar virtual world but equipped with an array of tools and in-game abilities. They are presented with a series of tasks, often called quests, that set specific goals but don't tell the players exactly how to accomplish those goals. To progress, players must experiment with the tools at hand to see how they can interact with the world and its inhabitants. Through this process of experimentation and discovery, they construct an understanding of the world's underlying systems and how to work within them to accomplish their goals and complete quests. While in the world, players in an MMO can see the avatars of other players nearby and are commonly motivated to chat with each other to give each other advice or even collaborate on quests.

The unique affordances of massively multiplayer environments have been shown to foster scientific thinking, scientific identity, and inquiry skills both inside and outside the educational gaming space in games like *Quest Atlantis*, *Whyville*, and *River City* (Kafai et al., 2010; Barab et al., 2007; Ketelhut, 2007; Ketelhut et al., 2007; Nelson et al., 2007). The open-ended game play encourages a deep engagement in exploring systems and models, relying on the process of evaluation and argument to build knowledge (Steinkuehler & Duncan, 2008). To capitalize on the affordances of MMOs and to build on the commonalities between this type of game and authentic science inquiry, we set out to design *The Radix Endeavor* as an environment that deeply integrates STEM practices as core game mechanics and allows players to learn by doing in authentic contexts.

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Game and Learning Designs

To support these goals, the *Radix* game world is designed around systems that players can interact with and manipulate. Figure 5.2 shows players in the forest region, one of the five distinct biomes with unique fauna, flora, structures, and characters. In each of these biomes, players can engage in activities such as collecting data to compare the heights of plants in different regions. They can also experiment with running simulations to see how a species in a biome has evolved over time and manipulate variables to test out changes in the environment, as seen in figure 5.3. Players also have various tools that allow them to engage in the authentic practices of biologists and mathematicians. Some of the tools are open ended and creative, allowing players to draw geometric objects on scale maps, build fences, or create and share food web diagrams. The game play is centered on quests that target specific content areas in biology and math. These quests are designed to encourage players to explore the different systems and biomes as well as to engage in inquiry, problem solving, and collaborative learning

Figure 5.2
Radix players exploring the forest biome

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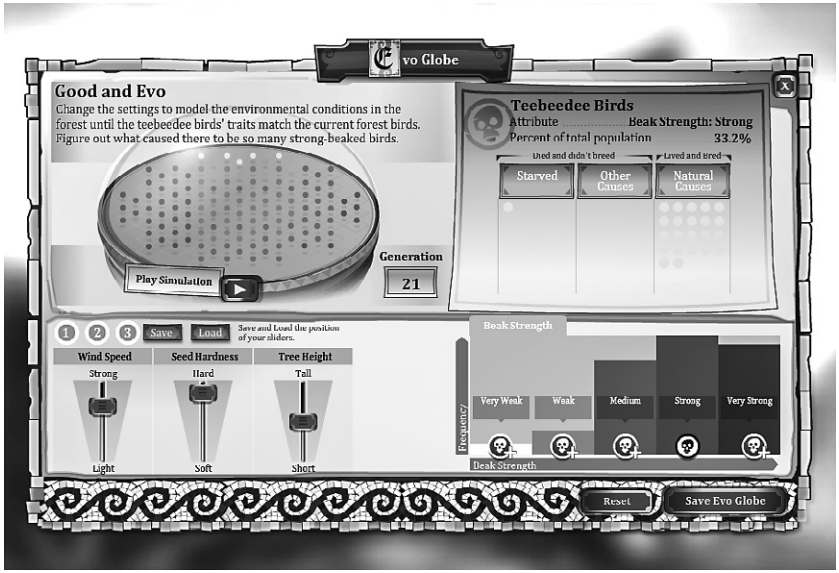

Figure 5.3
The evo globe, which lets players simulate changes in a trait over time

in order to complete the task and provide evidence needed to support their solution.

When a new player enters the *Radix* game, she finds herself in a grassland biome on the island of Ysola, an Earth-like world full of fictional plants and animals. She is likely to see the avatars of other players moving around the world working on tasks in the same area. There is a character nearby with an exclamation point over her head, so she talks to her to take on her first challenge, which starts the series of introductory quests. Once she has completed those quests she will be familiar with navigating the world, talking with in-game characters and using the basic tools for collecting objects, examining them, and analyzing data about them. From there, a wide array of other questlines is unlocked. The player can explore any topic area she is interested in or the specific ones that her teacher has asked her to work on. Each questline starts with one of the island's residents explaining some problem or question that is causing the people trouble. This way, the game's challenges are situated in a contextual narrative that gives the player a reason to care, and a motivation to solve problems that will save the island or its people. The player will then use her tools to explore the

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environment, ostensibly "messing around" but in reality experimenting and making discoveries. Through collecting and analyzing data, the player gains an understanding of the mathematical and biological systems embedded within the game world, such as Mendelian genetics or evolution. Once she understands each system, she can adjust the inputs to that system to get the outputs necessary to solve the problem. She then returns to the character in need of help to turn in an artifact or explain a solution, which requires not only an answer but also data that explain how she knows the solution will work. Quests take place across the *Radix* world in rich biomes, with different tools becoming useful in different domains. This brief overview provides a sense of the format of the game and the player's experience, setting the stage to next understand how STEM content and practices are built into the inquiry-based play style of *Radix*.

The virtual *Radix* world provides an environment where students can gain both content knowledge and the skills and practices critical to science understanding. The game covers four topics in biology—genetics, ecology, evolution, and human body systems—along with three topics in math: algebra, geometry, and statistics. These content areas were carefully selected to complement what students might be able to do in hands-on labs or activities, with simulations and longer time-scale tasks that are possible only in a virtual world. The particular content for each of the topic areas is aligned with standards from the Next Generation Science Standards (NGSS) and the Common Core state standards, including an emphasis on math and science practices. Throughout all the questlines in the game, players must use twenty-first-century skills such as collaboration and critical thinking to solve problems. This emphasis on skills and practices is critical to students as they engage in deep thinking in any domain, and *Radix* provides an innovative place for students to apply these skills.

The Player Experience

One of the key components in designing the game content and quests was to create a space where students could practice inquiry. This means that when players encounter a problem in the game, they must think through how to solve the problem and determine their own course of action. To illustrate this process and the type of game play *Radix* provides, we examine in detail an introductory evolution questline.

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The initial set of evolution quests in *Radix* were designed to guide players through a sequence of learning experiences that would fit together to build a larger picture of how evolution works. It starts out with a more guided format, giving players a fair amount of direction in terms of where to go and what data to collect. As players work through the quests, they are presented with more open-ended simulations and artifact creation tools. This design is a common way for MMOs to scaffold a new player's entry into the game, and it is also a useful strategy for scaffolding the development of players' data collection and analysis skills. An overview of the progression of evolution quests is presented in figure 5.4. While this shows a linear progression of quests, they do not always work that way. Certain questlines have more branching or varied quests served up to players. In addition, as players work through any questline, they are free to explore other areas of the world they find interesting, and they are also able to pick up and complete quests from other topic areas along the way. This means that skills and strategies players develop in each quest can affect their play patterns in any other questline, and they may interweave different experiences in this way. In this section, however, we focus on the evolution quests and identify the key learning activities as we present this sequence.

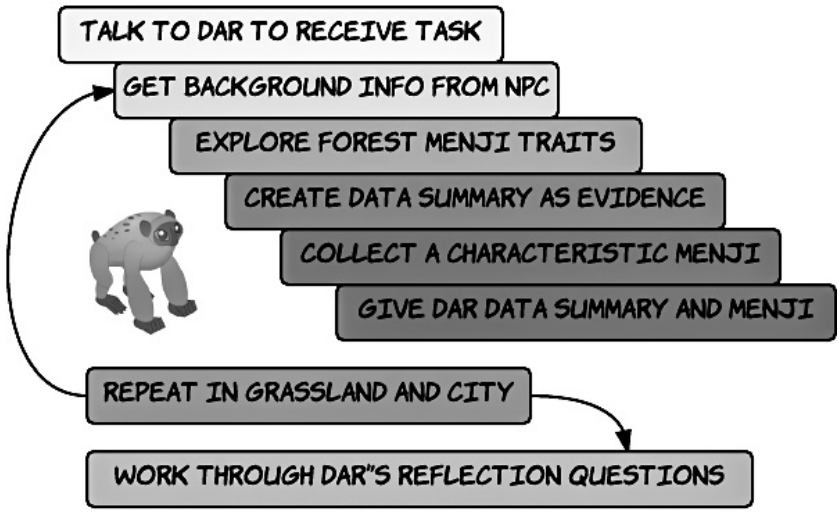
TALK TO DAR TO RECEIVE TASK
GET BACKGROUND INFO FROM NPC
EXPLORE FOREST MENJI TRAITS
CREATE DATA SUMMARY AS EVIDENCE
COLLECT A CHARACTERISTIC MENJI
GIVE DAR DATA SUMMARY AND MENJI
REPEAT IN GRASSLAND AND CITY
WORK THROUGH DAR"S REFLECTION QUESTIONS

Figure 5.4
Progression of the first evolution questline

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Embarking on the Quest

The evolution questline starts with players talking to Dar, an NPC (non-player character) who works for the ruler of the island, maintaining his menagerie of animals. She tasks players with discovering all the different kinds of menjis on the island and helping her collect one of each type. So players wander off to the forest to get started. They know they're supposed to find a characteristic trait but not which one that is. When they arrive at Lednem Wilds, players find a pack of menjis and figure out how to use the trait examiner tool, as shown in figure 5.5. After the first couple, they get the idea that they can discern the different claw lengths, fur lengths, and hand shapes on each menji. In addition, when they examine these traits, a record of each one is saved to their data library. So players realize that by examining a large quantity of menjis, they should be able to find out whether there's anything the menjis all have in common.

For many players, the uncertainty of which trait they're looking for and how to answer the question posed to them can be frustrating. This is a normal response, especially from students who are used to being asked

Figure 5.5
Examining menji traits in the forest

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straightforward questions that have a clear path to the correct answer. The uncertainty of figuring out how to research a fairly general question, however, is exactly where the value of inquiry learning lies. Players are placed into an authentic context, where they have to explore and experiment—there is no specific method given to them to tell them exactly how to find out the characteristic menji traits of the region.

Building the Argument

The next step of the quest involves data analysis and pattern finding. After examining a good number of menjis (usually ten or more), players may already notice a pattern emerging. They see that menjis have different kinds of fur and hands, but most of them seem to have long claws. If players haven't been keeping track, they can discover this by organizing their data with the data explorer, a very simple data analysis tool. Players try selecting a few different traits as the target variable until they find one that shows a distribution with a clear majority—claw length! Now even if they already figured out that forest menjis have long claws, they have a data summary report to prove that finding.

For players that aren't familiar with calculating means or filtering by an attribute, the tool helps guide them through the choices they need to make. This tool lets them "mess around" until they find a summary that provides meaningful evidence of a certain pattern. The use of the data explorer is one area where we've seen players greatly benefit from using each other as a resource and collaboratively making sense of how to use the tool effectively. Once they understand the tool, they can create a data summary, such as the one in figure 5.6, which shows the percentage of each variety in a population within the selected trait for the data collected. In this case, it shows that finding a forest menji with short claws is very unlikely; in fact, there isn't even one in this sample. This is what players have already experienced by exploring menjis using the trait examiner, but they then use basic math in an applied context as another way to talk about their discovery. The exploratory act of figuring out how to use a tool to accomplish a goal can be illuminating and satisfying—for many players, even as satisfying as finding the answer—because they have taken ownership of the entire discovery process. In addition, the act of creating a data summary, a piece of hard evidence for what they found, reinforces the importance of being able

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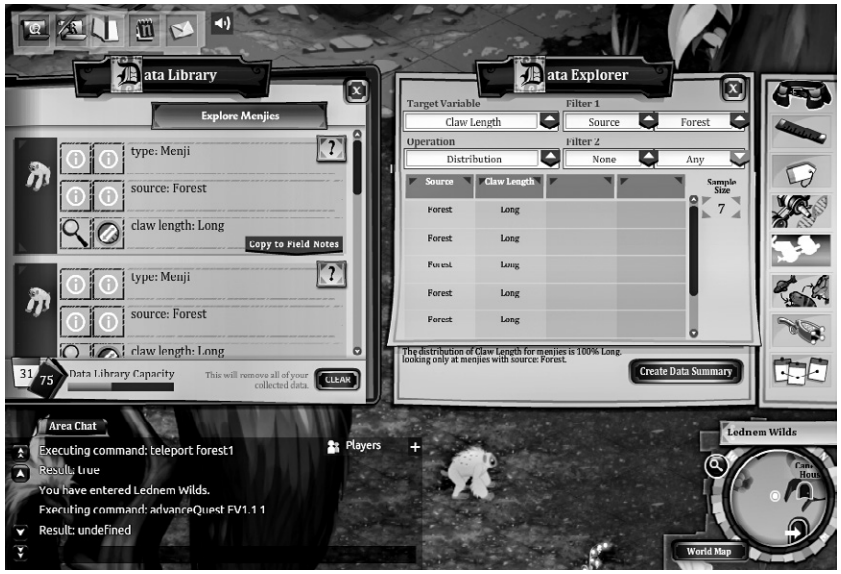

Figure 5.6
Using the data explorer to analyze menji data

to back up their discoveries with data. These elements make up a valuable learning experience around independent exploration, an authentic part of doing real science.

Repeating the Experiment

Once players have collected a long-clawed menji for the menagerie and created a data summary to prove its characteristic trait, it's time to look for the other special menjis. They search the world for menjis and find large enclaves in the grassland (figure 5.7) and in the city (figure 5.8). Now that they have identified a data collection and analysis method, they apply the same principles to discover that grassland menjis almost all have long fur, and city menjis almost all have narrow hands.

While it often takes players significant time and discussion with peers to figure out the forest menji quest, the grassland and city quests invariably go much faster. Repeating a similar task helps players practice identifying similar patterns and build confidence in their data analysis. It also provides the time to begin to reflect on what each discovery means on its own as well as what they have in common.

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Figure 5.7
Menjis in the grassland

Figure 5.8
Menjis in the city

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Reporting the Discoveries

After exploring the menji populations and successfully delivering the results, the last step is for players to explain what they have seen. When they return to Dar to deliver the menjis to the menagerie, she asks why the vast majority of forest menjis have long claws. During their travels, players have talked to Clawphur (figure 5.9) and found out that menjis eat jumples and cloud nuts, which grow high up on trees, and that they use their claws to climb trees. Based on this information, they should be able to report that menjis with long claws could reach the food while menjis with short claws may have starved to death. With this, the questline is complete!

By gathering similar information in each biome, players can begin to hypothesize about models of traits in a population. Dar's guiding questions help solidify their mental model of why certain types of menjis survive in certain areas while others don't. With data-backed evidence for the geographic trait differences, and hypotheses that can explain them, players have carried out a research study and engaged in authentic scientific inquiry by the time they have completed this questline.

Clawphur
It's good for animals with claws! It means they can climb trees to get food and get away from other animals that want to eat them, which helps them stay alive.
How do you know all that?
ILoveMenji
Area Chat
Result: true
You have entered The Menagerie.
Executing command: teleport forest1
Result: true
You have entered Lednem Wilds.
Players
Lednem Wilds
World Map

Figure 5.9
A forest NPC providing information on menji behaviors

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Systems for Exploration

The Principle of Designing Systems for Exploration
Games based on systems with interesting relationships that provide meaningful choices for players necessitate experimentation as well as analysis and interpretation of the outcomes.

When applied	*When not applied*
When a game includes systems made up of interesting relationships, players get an engaging experience of experimenting and making discoveries. They can try things many times and get slightly different results, necessitating the use of their analytical and interpretive skills.	A game without interesting systems often falls flat, with outcomes becoming fairly predictable regardless of what choices the player makes. While they are not necessarily bad games, they tend to require less deep thinking, appropriate for procedural content knowledge but not so much inquiry learning.

One of the key elements in creating a game space that supports inquiry and deep thinking is designing interesting systems. These should be systems that have a set of meaningful relationships, often mapped to a real-life system, where the players have some control over the inputs and must evaluate the desirability of the outputs. Usually the rules of the system are not all known to players when they start, so they must experiment and hypothesize about how the system works. Once they get the outcome they want and can reproduce it consistently, they have constructed a deep understanding of the relationships within that system, which is a valuable learning experience.

Each topic area within the game of *Radix* has a system embedded in it that models some real-world concept. The genetics system of inheritance patterns is an example of this with a very clear mapping. Plants and animals in the game have traits, and there is variety within those traits. Using tools provided in the game, players can examine each organism to identify its phenotype (outward appearance, such as flower color) and its genotype (alleles for a specific trait, such as Aa). When investigating a new species, however, they don't yet know which varieties are dominant or recessive, or even which inheritance pattern applies to a given trait. Based on the

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information they can obtain, players then use the breeding tool to mate two individuals and breed some offspring. The game runs its simulation of the possible resulting traits and randomly chooses from those for each offspring. Next, the player examines the individual offspring as well as views some statistics on the traits of the brood as a whole. By comparing what they bred and what offspring they got, through a handful of crosses, players can deduce how alleles interact for a particular trait, and therefore how the inheritance pattern works.

The process of probing a system to understand it is embedded in the quests students work through. In one of the genetics quests, players must help a character find enough glumbugs to make his glummy cakes. The problem is that some glumbugs are toxic, and players must find a way to reliably get large quantities of nontoxic glumbugs. It's clear that breeding them is the way to go, but the question is which glumbugs to collect and cross. So players examine glumbugs and conduct experiments, keeping track of which type of parents produce which type of offspring. Once they figure out that nontoxicity is a recessive trait, and once they have bred a generation of homozygous recessive bugs, they can then breed large quantities of nontoxic bugs for the baker. In this case, the bugs with certain genotypes are the inputs to the system, and the offspring (hopefully nontoxic) are the outputs. The system of relationships is built into the breeding tool, which models the complete dominant inheritance pattern, following the rules of Mendelian genetics. Working with a meaningful system in this context gives players the opportunity to create their own mental models and test them out, using inquiry skills and engaging in deep learning. This is very different from the way many students learn Mendelian genetics in schools, where they follow a procedure to fill out a Punnett square but don't always see it in the context of a larger system. Having students themselves make the connection between the way recessive traits work and actual organisms that have those traits is one of the benefits of building meaningful systems into a game like *Radix*.

While the genetics system is clearly modeled off an existing biological system, others in *Radix* may not exist in reality as they do in the game. These fictionalized systems are designed to create a context in which the application of the concepts become clear. The algebra questline is one of these: in a marketplace that doesn't accept currency, players must instead barter with the merchants. At the beginning of a quest players are given a

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trading kit with some starter objects, and at the end they can trade for gold bars at the pawn broker. The merchants don't all have the same perspective on the value of each object, however, and that is where the mathematical thinking comes in. If players start with three sizzgams, they must compare all the things they could buy with those sizzgams, and then compare all the things they could buy with whatever they now have, essentially testing out a trading path through the trades merchants make available. In addition, they have to evaluate for themselves where they need to end up. To obtain the most gold bars possible, they may take one path, but to maximize one type of object, they may take another path. In the algebra marketplace, the inputs are the trades players choose to make, and the outputs are what they ultimately end up with when they are done trading. The relationships in the system are the options given by the vendors and the broker, which determine what players can ultimately get out of the system. While there is no marketplace in the real world that functions in exactly this way, designing such a system let us create a space where players need to think about concepts like unit conversion, multistep problems, and quantitative reasoning, and apply those skills to reach their goals. This shows how a mathematical system can deepen both a learning experience and a game experience.

The breeding tool and the algebra marketplace are systems directly tied to STEM content and quest tasks, but there are also systems designed into *Radix* that support learning indirectly by making the exploration gameplay experience more authentic and interesting. This is the case with the trait distribution system that functions in the *Radix* world. As you walk around any biome, you encounter plants and animals whose traits you can examine. Game designers and content writers came up with each species, trait, and variety that can be found in the game, but they also specified the distribution of each variety across regions. As each creature is generated, their varieties of each trait are assigned randomly but according to probabilistic parameters. This means that the designers also had the opportunity to specify the distribution of each variety in each region, for example dictating that on average 80 percent of menjis in the grassland have long fur, and only 20 percent have short fur, whereas in other biomes, it may be 50/50. This particular trait distribution is at the heart of the evolution questline described previously, where players discover the concept of natural selection by finding out that certain varieties are more prevalent in certain

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places. In this system, the inputs are the distributions specified by game designers, the relationships are the manifestation of those distributions in creatures' traits, and the output could be said to be players' discovery of those relationships. This type of behind-the-scenes system can be powerful in making a game feel alive and in creating a rich world of exploration. In addition, well-designed game systems are versatile, often becoming useful in multiple ways. The trait distribution system in *Radix* enables certain quest mechanics in evolution, ecology, and statistics, as well as providing a rich and authentic context for players to freely explore. This feature helps students make connections across disciplines and understand a concept at a deeper, more abstracted level.

Complex systems are a valuable tool in educational games, but they are also prevalent in commercial games, which we can look to for inspiration when designing for learning. Many MMOs have an auction house, which at first glance may appear to be simply a location or tool but in reality is a rich economic system. Players earn or create objects, which takes time, skill, or both. They can then sell those game objects to other live players, who bid using an auction format. Different objects may be more or less valuable to different players depending on their progress in the game, or their chosen path through the game. So supply and demand comes into effect, the auction house is alive and ever changing, and players must carefully make decisions that will affect their subsequent game play. This type of game system was one influence for the design of the *Radix* marketplace, which despite being single player, also challenges players to think about how to determine the value of their objects.

Another well known systems-based game is *SimCity*. The original *SimCity*, along with its multitude of sequels and spinoffs, was at its core a system of relationships among elements of a city. Players make decisions and see what happens to their citizens' wealth, happiness, and other metrics, and by doing these experiments, they figure out something about how the game's city works. Some of those relationships are intuitive: if I add an amusement park, my people will be happier. But others may take more probing: if I build a nuclear power plant, how will that affect the neighboring residential zones, and in turn, how will those changes affect the residential zones across town? Players form hypotheses about how the simulation works, and they can test those hypotheses with the inputs they have access to. On a larger scale, players may even extrapolate some of these questions

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to the real world when they notice urban planning issues in their own communities. While *SimCity* was not a great model of urban planning, it did give people a vocabulary and curiosity to ask those questions. The city's relationships could certainly be more accurately modeled in a version whose goal was for players to understand realistic urban communities by playing the game. This potential for making connections among systems within the game and out into real life is something that learning games can capitalize on for both presenting content and practicing more generalizable skills.

Regardless of the complexity or subject of a game's systems, when they are robust and explorable, they make a game feel alive and drive the imagination of the player. The flowers you might breed in your first generation affect the flowers you can breed in subsequent generations, so it is more complex than a simple virtual experiment. Finding large blackburn birds in the desert doesn't mean you can assume they are large everywhere, and interacting with the system is what opens your mind to those possibilities. A robust system is not easy to design, but it doesn't necessarily have to be complex. Many interesting game systems are simple and elegant. The key to designing them is to recognize that the game experience becomes compelling when the models are rich enough to actually experiment, not simply input something and get out an answer. Consequently, that's when the experience of probing the system will stick with the player and help make connections in systems even outside the game.

The Multiplayer Experience

Social experiences are an integral part of learning, as we discuss in chapter 4. Opportunities for social interaction were provided in *Vanished* by designing challenges that required collaboration to solve them. Opportunities for social interaction are also provided in *Radix*, but through the design of the tools in the game rather than the design of the tasks. The goal of including these features was to contribute to the inquiry-style learning environment being created.

One fundamental feature of MMOs, including *Radix*, is that players walk around the world with their avatar, and as they do, they can see other players' avatars as well. This makes the world feel alive and can create a sense of community. Often if a whole class is in the same region during

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a class period, players know who the other players are. Other times, they may be students from other classes or other schools, but depending on the permissions set, they can use in-game chat to talk to each other. The chat is open ended and therefore doesn't direct players' conversations, but when they meet in the same area, say, the marketplace, they may guess that the other player is also working on algebra quests and strike up a conversation about how far they've gotten and what strategies they may be using. Similarly, once players have added each other to their buddy list, they can send each other in-game mail, including attached objects. This means that if I forgot to collect a jipsnout with a certain trait, and I'm now halfway across the world, I can ask a friend to catch one and send it over to me. Additionally, if I find a crazy new species in the swamp, such as a plaid schloggen, I can send one to my friend to share my new discovery. This type of social feature is designed to enable players' communication about quests and possible collaboration, without requiring them to engage with each other.

One of the more robust social features in *Radix* is the ability to "party" with other players. In typical MMOs this means players can form a group with a private chat channel, with many types of accomplishments shared across members. This enables groups to complete a task with less work for each person, or to achieve goals that would be too difficult for any individual player. In *Radix*, the partying feature centers on data collection. When a player examines the phenotype, genotype, or any other attribute of a species, that data is stored in his data log for him to analyze later with the data explorer tool. When that player is in a party, data that his fellow party members collect is also automatically stored in his data log. This means that he can carry out studies with larger sample sizes or that cover more geographical area. Many players have also discovered that it meant they could ask someone to collect certain pieces of data for them if they didn't want to walk over to that specific spot. In *Radix* this means that the work players can do in groups has a different quality than what they can do on their own. So even though quests don't force them to party, when they decide to try it, they may start thinking about the problem in a new way. Additionally, providing these opportunities for collaboration necessitates communication. When players want something specific, they need to use accurate language to describe the traits they are looking for or how many data points they need from each area. Collaboration and

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communication are important skills that students in classrooms aren't always called on to practice. The approach used in *Radix* to help build those skills is to embed opportunities for social interaction directly into the game play.

The multiplayer functionality currently built into *Radix* is content agnostic. That is, these features don't apply to any one topic area—they are equally useful in a genetics, evolution, or geometry quest. They are also not essential to completing quests in the game, which can all be finished by a single player. While there are reasons we built the first version this way, there is huge potential for other multiplayer experiences that tie directly to discipline-specific practices. For example, players might need to collaboratively draw up plans for a set of buildings, contributing to the same scale map. They would need to agree on a scale, split up the measuring of the buildings, and draw them on the map to the correct scale and in the correct place in relation to other players' buildings. By using the same shared map, they could check each other's work and give feedback on which spots may not be to scale. Another example is on an ecology quest, players might have distinct responsibilities that complement each other. So one player might need to reintroduce a species into an ecosystem, while another player breeds more of that species, and yet another monitors the effects on other species in the relevant food web. Tools would be designed for these specific purposes that also facilitate players' collaboration and integration of their ideas and contributions. By engaging with these social experiences embedded in content-based tasks, players would need to think on multiple levels about how to do their jobs, what other people need to know to do their jobs, and how to ensure that everyone's contributions work together. Running up against the different ways in which other players approach a certain task can be eye opening, but it is not something that happens often in individual learning experiences. A rich game world with well-designed challenges provides a safe space to make those different approaches visible and then work to integrate them into a solution collaboratively. This type of deep learning experience not only improves understanding of STEM concepts but also leads players to think in an open-minded and connected way. Well-designed games or software can be tools to both spark and sustain those valuable social interactions.

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Bridge Curriculum

The Principle of Making Curricular Connections
Skills and practices, not only content knowledge, can be taught within games in unique ways. Drawing out these goals explicitly in bridge curriculum activities can build on and solidify the learning.

When applied	*When not applied*
A game with meaningful ties to the curriculum, in terms of not only content knowledge but also skills and practice, provides a starting point to make connections to other activities. Thoughtful bridge curriculum builds on the game to create a rich array of extended learning opportunities.	When a game's curriculum is in a more informational or procedural style, opportunities to make meaningful connections outside the game are limited. It becomes difficult to design quality bridge curriculum that goes beyond practice problems and gets at complex concepts.

Radix was primarily designed for teachers to use with their classes in schools. We were careful to make it accessible to players outside school as well, but many of our design decisions were driven by a vision of how the game would be implemented in classrooms and incorporated into existing curricula. It is a large game with a lot of content, and it is designed to be played at multiple relevant points throughout an existing year-long curriculum. Students may take a little time to become familiar with the game and its pedagogy, but they keep coming back to it, playing for a week or two each time they come to one of the units included in the game's curriculum. From the outset, the vision was that the bulk of students' game-play time could take place outside class, when they were free to experiment as much as they liked and explore whatever areas of the world they were interested in. They could work at their own pace and not worry about how far the student next to them had gotten, while still taking advantage of the social features to communicate with others working on the same quests. Once students had had this personalized but shared experience working with the content, teachers could use in-class time to conduct activities that facilitate transfer, go deeper into certain concepts, and explicitly make connections to other related activities or topics. This approach builds on the concept of preparation for future learning discussed in chapter 3, in which having

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the game-play experience doesn't mean you're done learning; rather, it is just the beginning—setting a foundation on which future instruction and experiences can be built.

The game's curriculum is tied to the Next Generation and Common Core standards, with the most important tie being the skills and practices laid out in the standards and embodied in the game. In science these are things like modeling, scientific inquiry, and data analysis; in math they include optimization and problem solving. Although these practices are being given more weight in the standards, it is often not made clear how teachers should teach these skills that don't fit into a traditional procedural teaching approach. Games, especially ones that provide rich experiences, are one way to put students in a situation where they can practice those skills. Yet when it comes to both content and skills, completing a questline in the game does not imply that players will have discovered the meaning of adaptation or the idea of optimization all on their own. Some players who have prior knowledge of these terms do make connections, becoming cognizant of what phenomenon they are witnessing. For most students, though, it takes some additional activities to reflect on the game experience and generalize it to a broader context.

The use case for these activities can be compared to the field trip model that is common in schools. The value of a field trip is clear—students get to visit an authentic site, such as a zoo, history museum, or research science lab, and see things they don't usually get to see in person. They often have the opportunity to do hands-on explorations and talk to experts, engaging with material in ways they can't do in the classroom. To make the most of these firsthand experiences, students are often given guides or worksheets to complete while at the field trip site, which can help organize their thinking and situate their observations within the context of what has already been taught. Additionally, a thoughtfully integrated field trip will include related activities that take place back in the classroom. These activities may extend the learning or synthesize what students saw and connect it with larger concepts from the curriculum. Of course, because of time constraints and planning limitations, teachers don't always have the opportunity to carry out these kinds of activities. But it is easy to see that if learning ends when the field trip ends, there is a missed opportunity to deeply integrate hands-on experience with classroom learning.

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Similarly, games can be considered the hands-on experience after which learning should not simply be considered finished. Like field trip experiences, the learning in game experiences can be built on and magnified by closely integrating them into other class time. We saw this occur through *Labyrinth* materials that provided additional opportunities to apply the math concepts from those puzzles. Given the importance of this model, when *Radix* is used in schools a heavy emphasis has been placed on discussions and activities outside the game. Some of these activities were designed by the *Radix* team and provided to teachers; others individual teachers designed themselves to make connections to materials used in their own classes. We often call these activities bridge materials, because they are meant to bridge the game experience to a more formal learning experience. Regardless of who designs that bridge curriculum, the critical idea is that these out-of-game experiences must be thoughtfully designed and implemented.

Class discussions are one of the most basic, and yet underutilized, ways to solidify learning that can happen in a game or other hands-on activity. Facilitating a discussion in which students recap what they did and reflect on how the experience went can be very powerful. Often when a game is played during class time, however, the bell rings and the students leave, and the next day the teacher has to move on to the next topic. So class discussions don't always happen, but when teachers plan time for one, they can do a lot to help students make explicit the phenomena they explored in the game. For example, after playing the geometry questline, in which students complete partially drawn scale maps of an area of ruins, the teacher might start the discussion asking students what ratios they set up to find the missing sides of the buildings. Students may have different strategies for this, some finding the ratio of building to drawing, and some finding the ratio of width to length. Both are interesting variations on the same method, but without the class discussion, students may never realize that there are other approaches than the one they used. Next teachers might ask a more open-ended question as a thought experiment, such as, "What would happen if the plans were not drawn to scale?" This is a perfect question for a discussion as there is no right answer, but students are challenged to bring in what they know about areas other than math. During game play people naturally tend to have some tunnel vision, so some guided reflection is required to connect the idea of ratios to architecture, engineering,

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or social studies. Finally, teachers could introduce some authentic materials into the discussion. If they show a model train or a map with a legend, they can challenge students to identify the scale and compare that to the scale of their *Radix* maps. Making connections in this way can help students broaden their view of mathematical applications, as well as strengthen their conceptual understanding of scale at various order of magnitude. Teachers can also explicitly make students aware of the skills they have used, such as modeling or estimating, bringing in a layer of metacognition to their learning experience.

As illustrated, there is a lot of value in whole-class discussions. Yet it is not a format that enables a teacher to hear from every student equally. One *Radix* teacher wanted a format that could help her assess each student's understanding of the evolution quests she had assigned, so she decided to use a journal entry task. This is a very simple method that many teachers already use, and it is also perhaps one of the most useful when questions are carefully crafted. After her students had played through the menji questline involving different distributions of menji traits in different regions, this teacher wanted them to apply the concept of natural selection to a new situation. To scaffold the experience and retain the clear connection to *Radix*, she kept the question about menjis but added a new context. She asked the students to predict what would happen to the population of a group of menjis that moved from the forest to a dark cave. This is a good inquiry-based question in that there is no right answer, so whatever the students come up with has to be supported with evidence from what they have learned in *Radix* or other parts of their biology class. Some students said the menjis would improve their sense of smell, and others said they would adapt their vision to see in the dark. Regardless of the outcome, their teacher was looking for key elements in their answer, such as an explanation of the selection pressure involved, and a mention of the time scale over which this might happen. Building on the context set up in the game gave her a good way to conduct formative assessment in the middle of the evolution unit. It also gave her feedback on where she needed to draw explicit connections back to what students saw and did in *Radix*. For her, assigning a question that started with the game content but extended out was an ideal level of challenge for her students.

Another way in which bridging activities can help complete an experience with *Radix* is by taking an abstract embodiment of a concept in the

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game and helping students discover what that same concept looks like in a formal academic setting. The algebra marketplace is a perfect example of a questline that makes people wonder where the math was after playing it. This is because there are no traditional math problems or equations that appear in the marketplace, so many players feel as if they are just trading goods. Players using the bartering system are in fact doing mathematical reasoning but it is also important for them to be able to express their methods with math symbols. So, one useful bridge activity is to show two vendors' offers and ask students how they could determine which one has a better deal. To do this, students will end up writing equations such as $5s = 3t$, where s is a snipsnap and t is a torrac. They can then replace the variables with values from the broker, or with other equivalent goods based on the vendors' offerings. After students go through some of this, making their own meaning of the equations, they will eventually realize that these equations and variables aren't so different from the ones they use in their textbooks and worksheets. This is when teachers can drive home the point that equations are not just right or wrong answers on a test, but they are actually a useful tool we can use to communicate and solve optimization problems like the ones encountered in the market. In this case, neither putting the equations into the game, nor bringing the market into the real world, would work quite as well as having two separate experiences and then making a connection between the two. We can't expect students to spontaneously make these connections on their own, but by planning and facilitating a bridging exercise, teachers can create a learning experience that will stick.

For teachers that have more flexibility or time in their curricula, there are even more constructivist and project-based activities that can effectively build off a game like *Radix*. They could have their students work through the ecosystem quests, constructing food webs and analyzing the ecosystem simulation tool, afterwards using a tool like *StarLogo* to create their own food web simulation to respond to different events. Students that have played the human body questline could extend the diagnosis tool by researching real afflictions and adding them to the game's *Big Book of Diseases*. Students could even design a *Radix*-inspired educational game to teach the same concepts to younger students in their school. Whatever the activity is, it should help students make their own connections from game content to other school content, or from game content to their everyday

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lives. And it should help them reflect explicitly on what they are learning and how they are learning it. When creating games for deep learning, we cannot assume that players will learn without a teacher, but we also cannot assume that they will learn simply by having a teacher there. What teachers do with the game and how they do it is of utmost importance and must be as carefully designed as the game itself.

Culture of Inquiry

The Principle of Creating a Culture of Inquiry
An inquiry-based game must be supported by a culture of inquiry in the surrounding educational setting. The expectations set outside the game influence players' sense of ownership and motivation inside the game.

When applied	*When not applied*
In a classroom with an existing culture of inquiry, students have the time and space to try, fail, and figure things out for themselves in a game. They ask each other questions and consult outside resources. The teacher stands back but offers resources, conceptual help, and encouragement.	In a more teacher-centered classroom, students continually ask for clarification on what to do and whether they're doing it right, and teachers are compelled to answer everyone individually. As a result the teacher is often overwhelmed and underprepared, and everyone involved gets frustrated with the process.

Inquiry-based learning is built around the idea of learners identifying their own interests, asking questions they want to explore, and then conducting activities independently to construct their own knowledge of the topic. Skilled inquiry teachers act as facilitators in the process of synthesizing knowledge and solving problems in an open-ended educational space. Although *Radix* was designed to create a space that fosters inquiry learning and exploration, a completely open-ended game would leave players confused about where to start and what to work on. Therefore, game designers aimed to strike a balance between directed quests and open-ended experimentation. In many quests, this means that a problem is presented to the player, and a question is posed. Often the game goes so far as to suggest a tool that may be useful in solving the problem, and players are aware of

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what type of artifact they are expected to turn in. As for what to do and how to solve the problem, though, players are on their own to experiment and see what works before ultimately settling on a solution. This creates a space for inquiry activities that may take some students outside their comfort zone, but provides the opportunity for authentic discovery and problem solving.

Another game that does a good job of creating an inquiry experience in a digital space is *Portal*. *Portal* consists of a series of puzzles in which players must use a portal gun to create portals between flat planes laid out in a test chamber. Because momentum is retained while traveling through the portals, players must experiment to figure out what trajectory will help them reach their goals. While the room design and the tool available create constraints, players can create portals anywhere, and they must experiment to see what happens while figuring out how the world works. Digital games, as designed and programmed experiences, by definition have constraints and directed goals. In a good inquiry game, these bounds work as scaffolding to help the player understand what they can try and where they can push those bounds. Players usually have an expectation of independent experimentation and repeated failure along the way to success. There is situated feedback, but no one telling them exactly what to do, which creates a feeling of ownership and satisfaction when they figure out for themselves how to complete a level.

The preexisting expectation that you will have to figure out how to use portals by experimenting is key to a player's enjoyment and success in the game. Unfortunately for games designed for in-school use, this expectation does not often exist in the classroom. The most prevalent teaching methods consist of a teacher who has the knowledge, students who are supposed to follow instructions, and problems that have right answers. This is true for textbooks, worksheets, and even many science labs done in schools. Because this is the norm, students and teachers both bring certain assumptions with them even when implementing an inquiry-based game like *Radix*. What can happen in this situation is that when students are presented with a challenge in the game, their first response is to ask the teacher, "What do I do now?" and "Am I doing this right?" In turn, the teacher, who is used to the role of dispensing knowledge, feels responsible for answering all her students' questions and looking over their shoulders to check their work. In a large class full of students playing a game

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in different ways and at different stages, keeping track in this way is not feasible and, more importantly, counterproductive. Trying to fit an inquiry activity into a didactic frame is doing a disservice to everyone involved, because the tasks at hand will feel incredibly frustrating, and no one will reap the benefits of independent exploration. The key point here, though, is that we can't fault the students for trying to follow directions as they've been taught. Nor can we fault the teacher for trying to answer students' questions and help them along the way. These are behaviors that are so ingrained because of the classroom culture that we all grew up learning in. It's what we're used to, and it's not easy to change years of those practices. Nonetheless, there are ways to overcome these challenges and prepare learners for an inquiry experience.

For example, Kolodner and colleagues (2003) describe how they create a culture of collaboration, independence, and scientific reasoning in the *Learning by Design* curriculum. This was an approach to middle school science learning designed by researchers and learning scientists who worked to address some of the big challenges in classroom inquiry learning. Before delving into the inquiry-based science activities, they designed "launcher" units in which students watched professionals engage in scientific practices involved in problem solving. The students worked together to identify the investigation, argumentation, and other practices the experts were doing, which helped create community and acclimate students to new classroom norms. After that, the designers worked to "ritualize" sequences of activities to make them come more naturally to the students, such as designing an experiment, then running it, and finally reporting on it. Making these science practices explicit and recognizing when they were occurring helped students understand what was expected of them in the class and as a community. These methods were implemented in the *Learning by Design* project to prepare students for design challenges and construction tasks. Although the *Radix* project was centered on a video game, both involved curriculum that allowed students to take ownership of their own learning. As we have seen, simply providing that type of opportunity does not automatically change the expectations of the people interacting with the intervention. That must be done over time and with intentional changes to the classroom culture and conversation.

To bring about this kind of cultural shift in *Radix* classrooms, our first step is to make teachers aware of the difference in approaches so that they

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know what to look out for. They do so many things unconsciously, such as standing in front of the classroom to explain something, or giving an answer because it's the fastest way to impart information. Bringing these actions to the front of their minds helps them notice the ways in which they create a didactic classroom culture. The next step is for teachers to explicitly tell their students that during *Radix* game play, learning may feel different, and they may not get the answers they want right away. Some students like this idea, and some don't, but they appreciate being told up front what's going to change. Finally, teachers can use some specific strategies to promote inquiry. A teacher in one *Radix* school we worked with had a "Three Before Me" policy. Any time a student had a question, they were not allowed to ask the teacher until they had consulted three other sources. These could be fellow students, the Internet, or the class wiki, for example. When they came up to the teacher, he would ask them to explain which three sources they had already tried. By being consistent with this policy, the teacher helped his students know what to expect, and they got used to giving each other more advice. In addition, this teacher acknowledged his students' frustrations and talked to them honestly. When they were stuck on a quest, he would tell them that getting stuck was part of the learning process, remind them about the last time they had figured a problem out, and encourage them to keep going. Gradually over the course of a semester, students got used to the change in expectations and came to enjoy the independence of figuring out how to use the world map or build a perfectly sized animal pen. They felt a strong sense of accomplishment each time they turned in an object they had created, and they were quick to give each other help and encouragement. *Radix* became almost like a club that everyone in this teacher's classes was a part of. This case demonstrates the strong community that can be built around a common experience of a game like *Radix* when the game's approach and classroom culture support each other.

When implementing an inquiry-based game that is different from the activities usually done in schools, some amount of disconnect between the old and new approaches is inevitable. That disconnect is not to be feared, however, but rather a motivation to analyze the existing classroom dynamic and an opportunity to purposefully make changes. In fact, *Radix* can be seen as an on-ramp to more general inquiry-learning techniques, as it provides an entry point for teachers to change specific aspects of their

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practice, giving them a focus as they get a feel for the role of an inquiry facilitator. The task of making changes and moving the needle in this area is not just for the teacher, but should also involve the game designers and curriculum developers. Designing an amazing inquiry-based game is not enough to be successful in an actual classroom. In addition, we must work to design the classroom culture that will support the game's approach and help players flourish in and out of the game world.

School Systems

The Principle of Working within an Educational System
School districts and other educational systems must be taken into consideration in the design of any game that will function within those systems. Games that are designed thoughtfully and flexibly will be more accessible and easily adopted.

When applied	*When not applied*
Resonant games used in a school system that is amenable to new pedagogies, or by a teacher who is able to patiently adapt to the constraints, will have the foundation needed to build an engaging learning experience. These can result in examples of successful implementations to be used as models for other locations and users.	Implementing resonant games in a school system that is not supportive, whether it be technology support, administrative vision, or parental expectations, can be a losing battle. Teachers can end up spending their limited time defending the intervention, which means less time for lesson planning and design, leading to a less successful implementation.

It's easy to see how the design of a game and the design of its implementation create an educational experience for students. What may be a bit less obvious is how the design of the preexisting school system can support or hinder that educational experience. School systems go beyond the classroom and beyond the school, shaped by policies and decisions at the district level. In fact, they go beyond the district level to the national culture and history of education, which has a huge impact on the expectations of teachers, administrators, and parents. These spheres of influence are present in all types of educational settings, from public schools

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to private schools, home schools and afterschool programs, though the specific challenges and opportunities that arise may vary greatly between those settings. Although *Radix* has been used in all types of learning environments, we focus here on public schools because they make up the bulk of our *Radix* users, and they are where resonant games can have the most impact.

When implementing an innovative pedagogy, we must work within several constraints, and while those vary by schools, districts, states, and so forth, some common themes emerge. For digital interventions, technology is often a major barrier, and not just whether a school has enough working computers. Teachers may have trouble booking the computer lab or laptop cart during the week they want to cover a certain topic and often have no access during computer testing months. There may not be reliable Internet or enough bandwidth. Teachers are often restricted from downloading software or plugins they need, and IT staff are spread so thin the school year may be half over by the time they get to it. Websites may be blacklisted or necessary ports may be blocked, with control over that residing at a district-level office. The distribution and management of technology in schools has grown into a complex system unto itself, and these issues can often result in a teacher ending up with limited seats or no connectivity when students show up for class. This can be mitigated in the design of the game by providing meaningful ways for students to share a computer and game account. It can be mitigated in the design of the implementation by helping teachers prepare backup activities that take game content offline or expand on it in a whole-class activity. These are some of the strategies we used with *Radix* teachers, but the frustrations around technology are bound to be there. Despite these barriers, more and more schools are starting one-to-one initiatives, which means teachers are looking for good content and innovative ways to use the computers. This opens up the doors to not only use new software, but also bring in new pedagogy and skills, which presents a valuable opportunity for games not previously adopted in classrooms.

Another challenge for inquiry-based or skills-based resonant games is the lack of understanding of the value of games and student-centered learning. This stems from the cultural beliefs our society holds about what does and does not constitute good learning. In many people's eyes, learning happens when a teacher imparts information and assigns concrete tasks. This

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is how learning has been structured in our culture for decades, and as a result, it is the format that people are comfortable with and expect to see. Video games, on the other hand, are often seen as frivolous or indulgent, wastes of time, or just for fun, with no real value. Again, this is because the role of games in general and video games specifically has developed this way in popular culture, and most people don't yet understand the powerful educational potential of games. Both parents and administrators are some of the key stakeholders in a school system that are likely to have these expectations. Many students hold similar beliefs, however, whether consciously or unconsciously. Students that have been comfortable in the traditional learner role throughout their school careers can be just as resistant to change as the older generation. We've heard from students who said they didn't want to play *Radix* and would rather just stick to book work because they don't have to think so hard—they can just do the work, and it's done. This sentiment has been echoed among multiple students because it feels easier to keep doing what they know how to do, and because change is hard. Though difficult, one of the best ways we found to combat this with *Radix* is to show people firsthand how transformative a game experience can be. Let administrators or reluctant teachers watch a class playing *Radix* so that they can see the "aha" moments and the lively chatter that accompanies the game. Take students far enough into the game that they get drawn in by the rich world, the social experience, or whatever aspect ends up motivating them. Show parents that their children have actually learned from a game, and that they have done it willingly. It takes work to make these live examples happen, but they are the most powerful evidence we can show for the value of inquiry-based learning in games.

Perhaps the biggest barrier to embedding games into classroom curriculum is the combination of imposed standards and limited time. The people who write educational standards mean well, and in theory the standards make sense—a consistent set of skills and knowledge that we as a society agree are important to learn. Many of the new standards, such as Common Core and NGSS, even include skills and practices specific to the disciplines. All align perfectly well with a digital game, which can include both content and skills in its design, and *Radix* is a good example of this. The problem comes with the amount of content allotted for a given school year, and the testing that goes along with it. Even with standards like the NGSS in

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place, which don't actually cover as much domain-specific content, the textbooks and assessments being used are still very content focused and tend to drive the curricular goals. What we know how to test at this point is procedural content knowledge, and with limited time in the school year, teachers know they have to teach to the test. Assessments in the United States are a complex and rigid system, and we won't go into those details here, but it means that more authentic but generalized practices such as independent thinking, modeling, or collaboration often fall by the wayside. Teachers and administrators believe those skills are important, but they are not assigned a value within the system of schooling. The approach we've taken in *Radix* and other projects is to design a game that covers the shallower content necessary in schools, but that also builds in activities that foster deeper thinking. This "content as cover" (Klopfer, 2008) approach has seen some success, especially in teachers who recognize the importance of inquiry. In that sense, resonant games can be a good entry into schools by incorporating both types of learning in one intervention. Some of the learning experiences essential to inquiry, however, necessarily take significant amounts of time. Students need to wrap their minds around a question and try several different solutions before they devise a successful one. They need time to confer with each other, build on the ideas of their peers, and iterate on their projects. In *Radix* students could certainly save time by following step-by-step instructions on what to collect, what to breed, and how to complete a quest—but they would be missing out on the very pieces that give them ownership of the learning process. Inquiry-based learning is not an efficient method in terms of time, so it can be very challenging to fit the processes into discrete class periods or to fit the projects into a packed syllabus. Where we saw big successes with *Radix* were with teachers willing to give up class periods to game play and discussion and to put aside some of the standards to provide something they saw as more meaningful. Working within the system in this way is very difficult, and given the demands on teachers' time and class time, this is not something that all teachers can do. So until larger systemic change can be brought about, teachers are left to manage at the classroom level.

Schools, what they teach, how they teach it, and the interactions among stakeholders, make for complicated and hard-to-change systems. In designing games that will be embedded in those systems, it is essential to be aware of the barriers the game will face, as well as the opportunities

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it can capitalize on. It is useful to identify the goals of the game and its implementation, and pinpoint where those may differ from the goals of the school or school system. By being aware of what the challenges are, you can design for them as much as possible both in the game and in the implementation, finding areas where the game can be molded to fit the current educational landscape. This will help the game find success in today's classrooms. Nonetheless, as educational game designers, we also have a larger goal of working to change expectations and demands at the system level. One way to move incrementally toward that goal is to continue making and implementing deep learning games that can work in schools. As more stakeholders become aware of the value of alternative pedagogies and more practitioners become adept at utilizing them, the ecosystem will in turn evolve into a more friendly place for students to have those learning experiences.

Professional Development

The Principle of Providing Professional Development
Teachers using innovative games that involve alternative pedagogies need training, support, and access to peer communities to effectively implement those games.

When applied	*When not applied*
Teachers that have access to quality and ongoing professional development will start with a stronger understanding of how to implement a resonant game and will have the tools to continue improving their own implementation. Teacher communities provide a venue for sharing experiences and advice, making new pedagogies feel more accessible and attainable.	Teachers implementing resonant games without a professional development experience or the opportunity to learn from other teachers often miss the mark on elements of an implementation that are important to foster. They are certainly still capable of using the game, but they often wonder why it didn't work out as they envisioned or why students aren't engaged.

When an Olympic tennis player traverses the court, wielding her racket effortlessly, she makes the sport look easy. That's because she has a passion

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for the game, but what you don't see are the years of practice and all the people supporting her behind the scenes. Olympic athletes have coaches, trainers, dieticians, and managers, not to mention supportive friends, family, and fans. This support enables a tennis player to learn to use the tools she has on the court and become an expert. You can be sure the first time someone handed her a racket, she wasn't using it to serve a ball at two hundred kilometers per hour. In many ways, teaching in general, and teaching with resonant games in particular, should be thought of similarly. The first time you give a teacher a complex game, no matter how well designed, he can't be expected to implement it expertly. He needs to have a year or more of implementing the game, getting a feel for what works and what doesn't, before he will start to really feel comfortable in that arena. He also needs those coaches and trainers—perhaps not as numerous as the Olympian, but he needs people who are experts in learning games to tell him what's important and what isn't, and to provide an objective lens on what changes he could make to his technique. Finally, he needs supporters, often in the form of fellow teachers going through the same learning process, but also in the form of administrators who are providing resources and space to experiment, and who are putting the word out that those game-play experiences are valued. Teaching with games is a skill that should be developed like any other, and in the education ecosystem, the necessary training and support often comes in the form of professional development (PD).

Teacher PD sessions can come in many forms, and *Radix* drew on several approaches to support teachers interested in implementing the game in their classrooms. We had groups of teachers come to our offices to participate in day-long training sessions. We offered to conduct sessions onsite for schools that had groups of committed teachers. We held monthly webinars and office hours for teachers to get advice from *Radix* staff as well as other teachers. In addition, many of the resources and recordings from these sessions were available online. Some of the sessions covered the basics of how to play the game, set up classes, and use the tools and resources available. Other sessions went more deeply into conducting transfer activities and thoughtfully designing a *Radix* implementation. All the sessions focused on inquiry learning in a game and how to create a classroom culture conducive to that type of learning.

We wanted to make it clear to teachers that it was okay to not have all the answers, and to encourage them to guide their students to other resources.

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As this is not a role that teachers are all used to taking on, we knew it was a big part of developing their skill in facilitating learning games. Despite this being new to many teachers, most of them can understand the value of it theoretically. Actually becoming a facilitator, however, rather than simply a director in the classroom was much more difficult. That part took ongoing time, encouragement, and feedback. In a few cases, as part of our research study, we even had the opportunity to give a teacher a live demo of what an inquiry-based classroom could look like with her students. This really gave teachers a concrete picture of what it should look like and how their own students could respond and change given the opportunity to take the lead. Although doing this one on one is certainly not scalable, it is a model to inspire PD design, whether it be connecting expert game-based teachers with novices, or simply providing video resources of model *Radix* classes. The key is to simultaneously show teachers what a successful *Radix* implementation can look like and give them the time and space to experiment and practice their craft.

Another wonderful professional development resource for teachers is other teachers. In some cases, it may be teachers who have used a tool or approach already, but it can also be fellow teachers who are going through the learning process at the same time. To extend the *Radix* PD past the formally organized sessions, we set up an online discussion forum for teachers to ask questions and exchange ideas. Here they could ask about where to find things in the game, clarify biological concepts, or share extension activities they found successful. This was the type of online community that we had hoped to grow among the *Radix* user base. Online communities can be difficult to foster, however, especially within a group that is pressed for time and not always comfortable with online tools. The *Radix* teacher forums didn't get a lot of momentum going within the pilot year, but this area could be further designed and grown into a valuable resource. This is generally true for many of our more traditional forms of PD—as a program gets more refined and systematic in how it's run, and participants become increasingly comfortable in online communities, we can bring more and more of the PD opportunities into the online space.

In terms of community, what we did see on a smaller scale was teachers interacting within schools, where there were multiple teachers using *Radix*. In these situations, teachers did troubleshoot and plan lessons together, and they found it immensely helpful, not to mention more enjoyable! In one

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case, two science teachers even created their own *Radix* wiki as a resource for their students. In that school, what started out as a small community of *Radix* teachers generated excitement and grew into an active community for all students playing the game. This is much harder to create when there is only one teacher implementing something new.

It also greatly benefits from including administrators in the community. Involving science coaches, curriculum chairs, or even principals in the PD sessions, or inviting them into the classroom on *Radix* days are a couple of ways to get them on board with a shared vision of new approaches to teaching. Support from those administrators can make adopting a new teaching tool feel more accessible, and it contributes to the excitement of a new initiative in a school, which is key for the sustained motivation of both teachers and students. Creating a community around an educational game that includes students, teachers, and admins, where they all feel a part of something bigger than their own classrooms, is a huge step toward normalizing the use of complex learning games in schools. The more people in a school using a tool and talking about what went on in their classrooms, the more others will see the value and feel motivated to try it. This way the community continues to grow within and among schools, leading to more adoption and further improved teaching practices.

The Complete Package

The principles described in this chapter emerged as key design principles in two ways. We had many of them in mind at the outset, when we began designing the game that would come to be called *Radix*. These principles and many more guided our design, prototyping, and play-testing work in the development phase. In addition, many of the principles emerged as we began to see teachers using *Radix* in myriad ways "in the wild" of their classrooms. Observing *Radix* sessions and talking to teachers about what they saw working well and what they struggled with helped us solidify these most influential principles in implementation design.

Note that none of these elements are all or nothing—every piece of the game and each implementation can be placed along a spectrum of embodying the concept in the principle. Throughout the *Radix* design process and pilot year, we saw instances of every combination of these principles. There are seven topic areas in *Radix*, and in an ideal world, we would have designed

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and developed them all equally, but in reality, some quests are more inquiry based than others, and some tools foster more social experiences than others. Teachers' understanding of inquiry and their ability to attend PD varies for many reasons, and the *Radix* pilot only followed them in their first year of implementation. Different states have varying levels of technology infrastructure and are adopting standards in different ways. These are just some of the reasons for the wide variation we have seen. While we present these principles as ideals, in reality teachers each have their own goals for implementation, and the right amount of each element varies depending on the setting and learning objectives in a particular classroom.

Finding the balance that is right for each game and each implementation, and understanding how these elements interact with each other, is where the real design work comes into play. Some teachers who implemented *Radix* saw it as mainly fluff rather than serious content. Other teachers used it directly to teach evolution or genetics. And some teachers weren't looking for content at all and only wanted to provide a self-directed inquiry experience, with math content as a bonus. In some cases, teachers felt the game worked great in their classrooms, but as designers, we thought it wasn't living up to its potential. And teachers who felt frustrated and thought the game was a dud might have had a completely different experience given one or two small tweaks to their approach. This wide variety of user experiences is inherent to a resonant game with rich content and opportunities for deep learning.

When designing a resonant game, and evaluating its success in the wild, we must understand the need for the complete package—that is, how the execution of all these principles work together to nurture that delicate plant of inquiry and create opportunities for deep learning. In many cases, simply having each element present is not enough; we must also understand how they affect each other and how the seed is planted to begin with. A teacher who creates a classroom *culture of inquiry* and freedom is setting the stage for students to explore the meaningful *systems embedded in a game*. The exploration of those systems results in learning through a teacher's skillful implementation of bridge *curriculum that makes important connections* visible. Teachers get better at doing this over time with the help of practitioner communities and *professional development*. And they are supported (or challenged) in their endeavors by the *educational system* they function within. Each principle has a relationship with the other principles, and

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with many more not discussed explicitly here. With certain elements missing, the package is not complete, and learning may not be supported to its fullest potential. But with each piece in place to support the others, the impact of the core game experience is amplified to the point where it can create connections never imagined by the original designers.

These are not plug-and-play games for which an educator can read a teacher's guide and use it the same way teachers across the country are using it. The ability to weave offline and online, in-class and out-of-class learning experiences together is part of the inherent value of a resonant game, but it also requires a commitment to the pedagogy. The design principles presented in this chapter can be applied to support that pedagogy, and they can be used on a wide array of games big and small. Considering these aspects will help embed exploration into the game and embed the game into the system it must function within. It will also help make the game resonate with classwork and the outside world, connections that are of the utmost importance for deep learning. This design process takes hard work on the part of the game designers, curriculum designers, practitioners, and even players, but when all the elements come together, it can be an unforgettable learning experience for everyone involved.

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6 Beetles, Beasties, and Bunnies in Your Back Pocket

As a single footstep will not make a path on the earth, so a single thought will not make a pathway in the mind. To make a deep physical path, we walk again and again. To make a deep mental path, we must think over and over the kind of thoughts we wish to dominate our lives.

—Wilferd Arlan Peterson

Many of the games presented so far are long-form, immersive games, in which players become deeply involved in the game play during a given session. Yet, resonant games can also take the shape of short-form, casual games, commanding players' attention for shorter periods but drawing them in more frequently, thus becoming part of the fabric of their lives in a different way. The events and places that become meaningful in our lives emerge in various ways. Many of us have special memories of a summer camp or vacation home that we visited regularly as children, perhaps spending a fun-filled week, or month, each year. It's plain to see why those intensive experiences create so many memories. Then there are places that at first glance seem less formative but are integral parts of our lives as well—the coffee shop we visit every week or the park we walk through on our way to work. While there may be fewer eventful moments in these places, the frequency of our visits makes them memorable parts of our lives, and later on, we may look back on them as fondly as the vacation destination. That repeated walking over the path creates a deep impression in us. Similarly, games can be integrated into our lives and implanted in our memories in these two different ways. Students who play *Radix* for full class periods during their evolution unit may look back at the end of the year and remember the triumph of finding that long-haired menji because they spent concentrated time immersed in the game world. But students who play *Beetle*

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Breeders ten minutes at a time, at various times of day throughout their genetics unit, will be just as likely to look back at the end of the year and remember all the times they bred the right traits in just one generation—precisely because the experience was not concentrated but rather repeated and spread out across many moments of the students' lives. We see this play style in numerous commercial games—players remember senior year as the year they played *FarmVille* obsessively with their friends; or they immediately associate *Candy Crush* with their first job because it was their go-to game on the subway commute. The experiences discussed in this chapter belong to this game genre: mobile, casual games that can fit into players' lives in various ways. These "ubiquitous games" have many design elements in common with other resonant games, but they also have some special considerations worth examining.

Ubiquitous games, or ubiq games as we call them, are so named because they can be played anytime and anywhere. They are designed as mobile games, with a casual game-play style and a focused content area for learning, which provides a number of affordances.

- Ubiq games can be *easily accessed on a personal device* such as a smartphone. For many learners, this is a device they have with them all the time, and it's a device they often have in their hands. This increases the ease and likelihood of opening up a game for a quick round of play.
- Ubiq games can be *played in short, frequent bursts* because they have game mechanics that consist of rounds, challenges, or some interaction that can be completed in a short time frame, perhaps five to ten minutes. These interactions are strung together to become part of a larger experience of exploring a concept or system, but each one is finite and provides easy stopping points. This means they will be exposed to the concepts in the game more frequently, with continuous reinforcement.
- Ubiq games are designed to fit into the *interstitial moments of the day*, in terms of both game design and technology. Players need to have individual accounts that save progress constantly. This enables them to put down the game when they need to, and to pick it up again when they have the chance. Unlike a game they might play in the computer lab for hour-long sessions, learners end up playing ubiq games while they're waiting in line, on the bus, or at home watching their younger siblings. This makes it more likely that they will actually spend time with the game.

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• Ubiq games can be *integrated into a curriculum* with increasing ease, as more and more students have access to their own devices, even if each student has a different device. Rather than taking up class time or teachers having to book the computer lab, playing ubiq games outside class time is more accessible and feasible than many other resonant games.

The UbiqBio Project

Ubiquitous Games for Biology (UbiqBio) was a project funded by the NIH from 2009 to 2011 that involved the design, development, implementation, and research of a suite of four games integrated into a high school intro biology curriculum.

We first worked closely with biology teacher consultants to design and pilot the games. Each of the four UbiqBio games covered specific standards-aligned curriculum points in the areas of Mendelian genetics, mRNA and translation, evolution, and food webs. The teacher consultants played a large role in identifying these as areas with which students often struggled. Each game also had a unique game mechanic, premise, and visual style, resulting in a diverse suite of games that balanced cooperative and competitive play, realistic and fantastical worlds, and simulation- and narrative-based games. Along with the games, a teacher dashboard was developed to collect game-play data relevant to each game's mechanics and content, which were displayed for teachers. Together with our teacher consultants, we then created supporting curriculum to help facilitate transfer and to make the games more accessible to other teachers.

The next phase was to work with a group of Boston-area high school teachers to implement the games in their classrooms. During each relevant curricular unit in the semester, teachers introduced the UbiqBio game in class and loaned their students Android smartphones provided by MIT. Teachers chose to assign the game either before, during, or after teaching the unit, as homework (or in some cases for extra credit), and students played outside class over the course of the approximately week-long unit. Researchers collected various data with the goals of learning more about (1) the efficacy, engagement, and feasibility of the UbiqBio games and approach; and (2) what types of casual games would best engage, motivate, and teach students. Throughout the course of this project, multiple design principles emerged that have informed our thinking on not only the ubiq

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games genre, but also what we now think of as resonant games. These are the primary design principles presented in this chapter:

- Designing adaptive experiences
- Codesigning with educators
- Integrating into everyday life
- Connecting data to practice

To help readers become more familiar with the idea of a ubiquitous game, we start by describing the four games that were developed as part of the UbiqBio project. An overview of each game is presented here with some discussion of the most interesting features of each. Then we provide additional examples of other games, both from within the Education Arcade and from outside designers, that highlight key ubiq game design principles.

Beetle Breeders: Mendelian Genetics

> Premise: Customers want to buy beetles with certain traits, and it's the players' job to breed them. Players choose the contracts they want to work on, then mate the right beetles to produce the desired offspring. They use their knowledge of Mendelian genetics to work with increasingly difficult patterns of inheritance and to maximize profits!

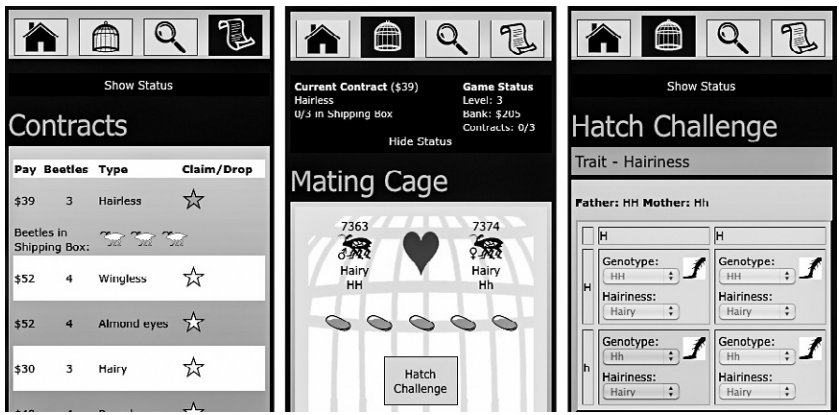

Figure 6.1
Beetle Breeders screen shots

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Beetle Breeders facilitates learning for students by allowing them to play through just one or two contracts per session, and still get the experience of trying different crosses and seeing the results right away. One thing that sets the *Beetle Breeders* game apart from the others in this series is the richness of the biology content. A basic Punnett square mechanic lets students experiment with a wide variety of inheritance patterns, which makes it relevant to a larger chunk of the genetics unit (figure 6.1). Players work their way up through the levels of the game, encountering more complex tasks as they go. This keeps the game interesting and makes it easy to see their progress as they move through the curriculum.

Invasion of the Beasties: mRNA & Translation

> Premise: Strange and scary monsters are taking over! Players must genetically engineer their own band of monsters suited to fight each opponent. They use the Universal Monster Genetic Code to research which proteins need to be synthesized. They adjust the nucleotides in the RNA strands and match the correct amino acids to create polypeptide chains without mutations. If players are successful, the resulting phenotype will give their monster the ability to defeat the enemies!

The biology content of *Invasion of the Beasties* is more specific, focusing on the concept of the universal genetic code and the relationships among nucleotides, amino acids, and phenotypes (figure 6.2). There are three levels of increasing difficulty, but since the game covers fewer biology concepts, "beating the game" feels more attainable. More than our other games, this one is very narrative based and character driven. The illustrations bring the game to life, and players enjoy giving each other tips on how to solve the puzzle of which phenotype will defeat each enemy. The models of biological systems (such as amino acids, the universal genetic code, and genetic engineering) focus on how DNA and proteins work conceptually, rather

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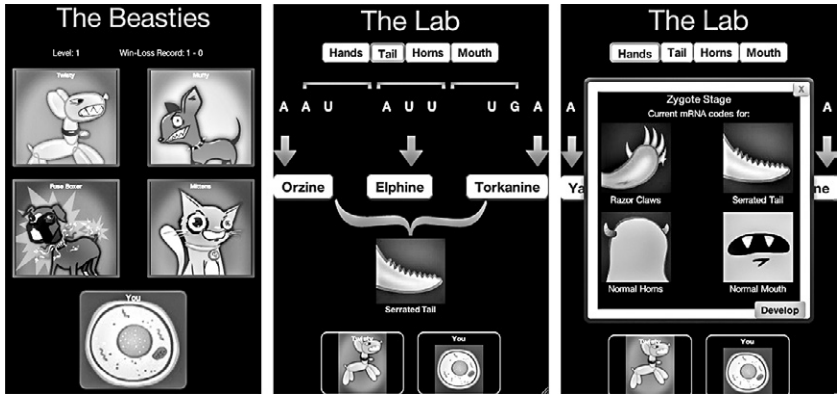

Figure 6.2
Invasion of the Beasties screen shots

than promoting memorization. These models are highly simplified, requiring teachers to highlight and explain the differences between the game and real biology, but also making the content more accessible and fun for students.

Island Hoppers: Evolution

> Premise: In a world full of islands, each with its own bunny population, small changes to the environment can have noticeable evolutionary effects. Players have the power to make environmental changes on their own island, such as increasing temperature, adjusting the local flora, and even introducing a virus. By collecting data over many generations and looking at the proportion of certain traits in their population, players discover evolutionary trends and learn to predict future population changes.

Island Hoppers poses an interesting design challenge because our goal was to take a very broad topic, evolution, which often contains many misconceptions for students, and break it down into bite-size chunks. We ultimately did this by specifying formulas for the back-end simulation, which enable players to fast-forward through time step by step to research each relationship. One element unique to *Island Hoppers* is the graphically represented

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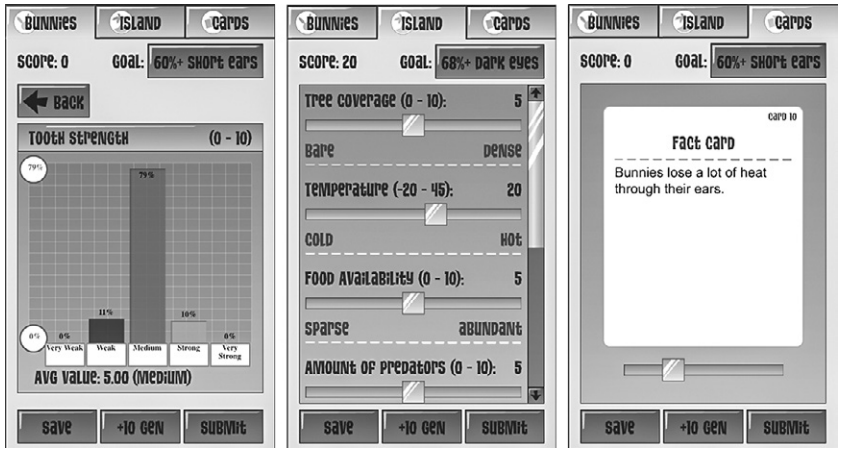

Figure 6.3
Island Hoppers screen shots

data and the use of histograms to display the breakdown of certain varieties of bunny traits (figure 6.3). Reading graphs is an important skill in science that is sometimes overlooked, so teachers value this feature. At the same time, the graphs provide information on whether players are making the right moves, so students are motivated to learn to read them.

Chomp!: Food Webs

> Premise: Mysterious species are connected in complex food webs that are under attack. Aliens have been chomping on these ecosystems, and each time they decimate one species, it has a drastic effect on the other interconnected species. Players must examine the relationships between species to understand and predict the population increases and decreases. If they can use this knowledge to determine which species was the latest victim, they will be able to restore the food web to its balanced state!

The main goal of *Chomp!* is to give students practice reading the energy flow of a food web (figure 6.4). It presents just two modes of difficulty, offering relatively less game play than the other games. Like *Invasion of the Beasties*,

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Figure 6.4
Chomp! screen shots

Chomp! uses fictional species content, which in this case compels players to think about the predator-prey relationships rather than relying on prior knowledge of real species. Because each food web is generated procedurally, no two players get the same sequence of puzzles, though the generated food webs do increase in complexity. As a result, instead of players' sharing the specific solutions they find for each puzzle, they are encouraged to explain the overarching concepts to help each other.

More Ubiquitous Games

The Education Arcade has created two other ubiq game projects that have both similarities and differences to UbiqBio. Educational games from other designers also share elements of this genre and are useful to compare, although we wouldn't classify them as ubiq games. These examples should help clarify what ubiq games are, while also highlighting the design principles that make ubiq games successful and unique.

Weatherlings

Weatherlings is a ubiq game developed in 2009 in collaboration with Nanyang Technological University in Singapore. It is an online collectible card battle game designed to be played on mobile devices but able to be played on any computer with a web browser. In *Weatherlings*, players manage a

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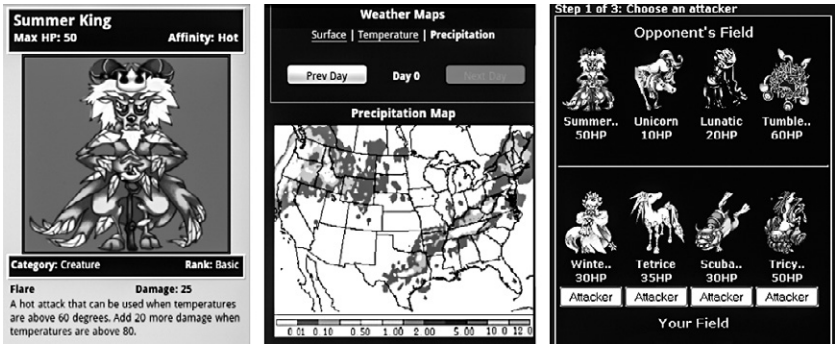

Figure 6.5
Weatherlings screen shots

collection of cards representing weather-dependent creatures and pit decks of their cards against other players' decks in battles (figure 6.5). These battles are set in actual US cities for which the development team has collected real weather data from the recent past.

One of the unique game-play elements of *Weatherlings* is the peer-to-peer interaction. While part of the game play involves deck building—collecting creatures and curating them into collections based on their strengths and weaknesses to prepare for battle in certain climates—this task is in preparation for battling with other players. That part of the game play consists of challenging other players to battle in arenas under certain weather conditions, which they must predict based on weather data. Peer-to-peer battles are turn based and can take place asynchronously, though players do often battle when they are physically sitting next to each other.

As part of the *Weatherlings* research done in a Singapore middle school (Klopfer et al., 2012), researchers collected data regarding the nature of student pairings. This research shows that the average student had 9.6 unique opponents (SD 4) over the course of four days. During the debrief discussion, students reported that they not only played against their friends (60%), but also played against whoever was available (75%). This is promising for ubiq games implemented in classrooms because it shows that if a mechanic is engaging, players will seek out people to play with, not limiting themselves to their group of friends. In fact, playing the game as a whole class provides players with more different people with whom to battle and discuss their outcomes.

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This kind of social game mechanic serves some important purposes, in terms of both engagement and pedagogy. Many commercial games have a social element, and middle and high school students are social by nature. The ability to do things with your friends or classmates makes the game more appealing and fun. In addition, the interaction provides a basis on which students can have discussions, whether it be recapping a battle they just fought or comparing strategies. These discussions are likely to involve at least some of the game content and educational concepts conveyed in the game. For these reasons, designing a social interaction into a ubiq game can be a valuable component.

Palmagotchi

Palmagotchi was a game designed in 2008 for secondary classrooms to teach students about the principles of evolutionary biology. The game operated on each player's handheld device—at the time Windows Mobile Pocket PCs—which students borrowed to play throughout the school day. For each player, the game simulates an island with various species of birds and flowers, each of which has various traits, such as beak length, featheriness, flower depth, amount of pollen, and so on. These traits have relationships within the back-end simulation that can affect things like the likelihood of each bird pollinating a given flower, or the amount of food a bird can get from that flower (figure 6.6). Players interact with other players to feed on others' flowers and to mate with others' birds. Throughout the span of the

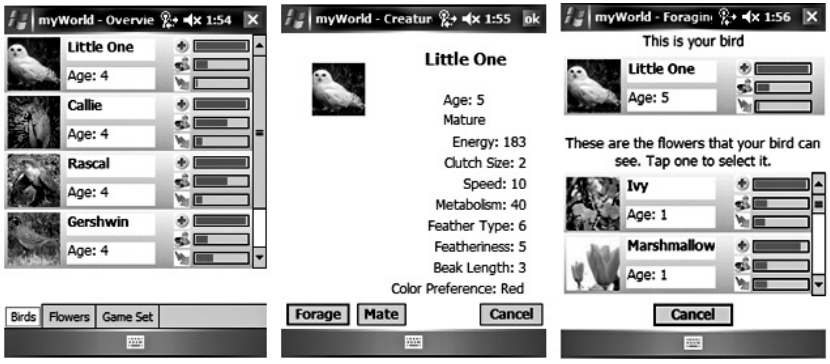

Figure 6.6
Palmagotchi screen shots

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game, the players can observe how certain aspects of evolutionary biology play out.

Part of what makes the *Palmagotchi* experience so powerful and engaging is the affective element. Much like its inspiration the Tamagotchi digital pet toy, this game capitalizes on players' desire to care for their pets and help them thrive. Male and female students alike become very attached to their birds, putting special care into deciding whom they mate with, and getting upset when their favorite birds die. This adds a special kind of motivation to pay attention to the birds' traits and the environmental conditions, and to frequently take their devices out in the hallway or at lunch to check on them.

Another thing that the *Palmagotchi* implementation did well is that it connected in-class activities to the game play, to provide different views on the concept of evolution. While students played the game, they experienced a micro view of evolution, paying attention to the individual birds and flowers on their island. They made daily decisions about which traits they cared about, which birds to feed, and which birds to breed, and this let them see in detail how those decisions affected the traits of their birds. Then, teachers conducted a whole-class activity in which students documented on sticky notes information about the traits of their birds at designated points throughout the game-play period. The whole class compiled these data points into a histogram on the board, and from this, students began to identify patterns of evolution that occurred across the whole region or a group of islands. This experience provided a macro view of evolution, showing how the population of a species on the whole changed over many generations, which no one student could visualize during game play. The game content and the activity were well suited to the concept being taught, and the design of the two together made clear ideas in biology that can be very difficult to teach. This example shows that when ubiq games are integrated into a curriculum in thoughtful ways, they can bring about deep learning for students (Klopfer, 2008).

Statecraft X

Another thoughtfully designed game-based curriculum that fits well into the ubiq games genre is *Statecraft X*, created by the National Institute of Education in Singapore. As the developers describe it (Statecraft X, 2016),

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Statecraft X is a 24/7 persistent-world, multiplayer game for students to construct meaning and identities in the context of citizenship education and social studies. The game is played on Apple iPhones. Its use is situated within the broader context of a learning program that explores how learning can be engendered across the boundaries of school, home, and other "outside" environments such as on the train and in the shopping mall.

In Statecraft X, students learn citizenship by playing the role of governors in a fantasy world. They have to ensure the total well being of the different peoples of the land, comprising trolls, elves, dwarfs, and humans. Satisfying the material needs and non-material wants of the citizenry being governed turns out to be a non-trivial matter. Support of the citizenry cannot simply be bought with money. Ideological issues have to be addressed. Coalitions have to be forged. Diplomacy has to be skillfully managed. Should players compete or collaborate for the successful development of statehood?

Game-based learning with Statecraft X seeks to create an open dialogic space within which issues related to the social studies curriculum and principles of governance at the secondary three level can be openly confronted and deliberated. Students' meaning making and identity construction are examined through the lens of the performance—narrative dialectic. Values and beliefs related to active citizenship are fostered through trans-contextual participation in game play that crosses the artificial boundary of in-school and out-of-school.

One aspect of *Statecraft X* that is worth drawing attention to is that it covers content in social studies. Although our previous examples all relate to science, ubiq games should by no means be limited to science or even STEM fields. Many concepts in humanities and social sciences can be a great fit for this genre, and the same design principles should apply.

Another key aspect is that this was designed as a complete *Statecraft X* program, with more in-depth curriculum than simply a game with some companion activities. Students that participated in *Statecraft X* played the game during out-of-class time over the course of three weeks, playing the role of governors in the game world. They also engaged in another fictional world that students created themselves using their imaginations. As a third component, they then investigated the governance of three real-world countries. Throughout these activities, teachers engaged students in meaningful dialogue, making connections between the three types of worlds. In a controlled study involving a postcurriculum essay task, researchers found that students who had completed the *Statecraft X* program wrote essays that "conveyed a strong sense of personal voice, awareness about current global and local issues, and an agency to act to achieve changes sought by the students," whereas the control group essays largely conveyed information read from a textbook (Chee et al., 2013, p. 24). This shows the power of a

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good learning game that is accessible to students, combined with effective curriculum implemented during class time. The combination of modalities can strongly support deep learning in any domain.

Other Educational Games

Numerous other educational games have some but not all the qualities of ubiq games, and these make interesting comparisons as well. As this chapter delves deeper into the design principles most relevant to ubiq games, keep in mind what it looks like when educational games incorporate certain principles and not others.

Sandra Day O'Connor's iCivics project has published a game called *Pocket Law Firm*, which is an iPad version of the online game *Do I Have a Right?* In this game, players run their own firm of lawyers who specialize in constitutional law. They decide whether each client has a right and match them with the right lawyer (iCivics, 2016). iCivics also offers civics curriculum materials and lesson plans that incorporate each of their games. *Pocket Law Firm* is broken up into small rounds of game play since players have to deal with one client at a time, and if they create an account, they can save their progress. Picking up the game again after a break, however, may take some amount of ramp-up time, because they need to remember which lawyers they had in their firm and which amendments those lawyers specialized in. While iPads are technically mobile devices, we're not sure they're really mobile enough for a ubiq game, in that we hope students will play when they're out and about. Given these factors, *Pocket Law Firm* is more geared toward sitting down for an hour-long play session than fitting into the interstitial moments of a player's day.

Touch Press Games is another brand that distributes educational games with some commonalities to ubiq games. Their offering for schools, via the Amplify company, consists of bundles of iPad games for STEM and ELA, including titles such as *Twelve A Dozen*, in which players must use their factoring skills and solve order-of-operations puzzles to save the world, and *The World of Lexica*, in which players explore a virtual world where they can play embedded ELA games and are motivated to read independently (Amplify, 2017). Touch Press Games has a unique implementation model in which they sell game bundles to schools and provide teachers with access to student data, but students are encouraged to play outside class, according to their own preferences. This means that students choose what games

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they're interested in and therefore may not be playing the same games at the same time. This certainly has its benefits but differs from the ubiq model, in which teachers can draw on students' shared experiences to conduct in-class activities. While some of the Touch Press games are more long form, like *Lexica*, and others are more casual, like *Twelve A Dozen*, they are all likely to be played in longer sittings on the iPad rather than on-the-go or in varied locations. Because of the iPad form factor, this characteristic is common to many educational games. While it doesn't detract from the quality of a game in any way, it does highlight the unique aspect of ubiq games, which are designed to be easily integrated into students' busy lives.

Designing Ubiq Games

We have just seen some examples of educational games that have similarities and differences compared with ubiq games. Naturally, countless casual games, which people play during spare moments of their day, don't attempt to integrate any educational content. These casual games provide us with some basic design elements that form the foundation of our ubiq games. While the goal of ubiq games is to provide a space to explore certain curricular concepts, they also need to be fun, playable, overall good games. To accomplish this, we rely on the work of casual game designers and scholars to inform our designs. Jesper Juul (2012) describes these five basic elements of casual games:

- **Fiction**: the way the game conveys its story to the player, which is typically positive and familiar for casual games.
- **Usability**: the way the player interacts with the game, which is typically via familiar controls or interfaces with thoughtful, easy-to-use design.
- **Interruptibility**: the frequency at which the game play can be interrupted while still making progress—typically casual games can be interrupted frequently both through controls (like pause) and by breaks in the flow of the game, such as those naturally occurring at the ends of levels.
- **Difficulty and punishment**: how hard the game is to start and proceed, and how severely the player is punished for failing—typically casual games provide an easy on-ramp for players but may develop into quite challenging games. They do, however, frequently allow the player to fail without harsh consequences.

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• **Excessive positive feedback, or "juiciness"**: the frequency and presentation of positive reinforcement for doing things well in the game—typically casual games provide a lot of gratifying feedback (both audio and video) for doing even small things right.

These elements can clearly be seen in wildly popular mobile phone games such as *Candy Crush*, *FarmVille*, *Angry Birds*, and many more. They have a cute aesthetic and are easy to learn to play. They consist of short rounds and can easily be paused or saved for later. They increase in difficulty, but not drastically, so that players can keep playing long term. And they frequently mark accomplishments in leveling up and unlocking new tools. People enjoy playing these games, and they are motivated to keep playing them, at various times of day and in a variety of settings. These are some of the key elements that we want to transfer to ubiq games, while infusing the games with learning objectives and building quality curricula around them. The design principles that we consider more specific to ubiq games are detailed in the rest of this chapter, and should be considered as building on the foundation of the well-established casual game principles.

Adaptive Experiences

The Principle of Designing Adaptive Experiences
Mapping the game's leveling system to a sequence of increasingly complex skills provides scaffolding and motivation for players. It also presents more opportunities for player agency and cross-curricular connections.

When applied	*When not applied*
Games that have carefully designed levels that map to content and skills pack more punch in one game. They are more appealing to teachers, who can connect the game to multiple areas of their curriculum, and they keep students engaged for longer, giving them larger goals to work toward and more agency in game play.	Games that have practice-based rounds or a variety of content without skill progression also serve a purpose as a learning experience. For instance, they can present more exposure to different examples of a concept. But they don't usually have the same impact on a player, either in terms of learning objectives or integration into students' lives.

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Casual game mechanics result in bite-sized game experiences that come together to form a larger challenge or undertaking. For example, in *FarmVille* and other games like it, each time you log in, you collect resources that have accumulated, you build new structures, and you check in on your friends' farms. But the overarching project, which you work toward little by little, is to build a thriving estate decked out with all the agricultural accessories you could want. When we apply this format to learning games, we must also think about the sequence of those smaller actions and how they build concept understanding over time. Based on the suite of UbiqBio games, there are two main ways to think about the function of these rounds, or levels.

Practice-Based Rounds

Practice makes perfect, and applying the same skills or processes to slightly different examples can be a good use of games. Especially in a classroom setting, where students are all given the same amount of time on a unit regardless of whether they understand it, a game in which students can practice as much or as little as they need can be quite helpful. In this case, the game contains a large quantity of replayable content, but the game mechanic stays the same. *Island Hoppers* illustrates the idea of practice-based rounds. It presents different bunny traits and different numerical goals, such as get 60 percent short ears, get 90 percent long ears, and so on. Yet the action of each round remains the same, which is to identify which environmental condition affects that trait, then make adjustments that will result in the desired population changes. Players are exposed to a wider variety of examples of relationships between selection pressures and traits, which can help them abstract the idea of natural selection. They also have the opportunity to read histograms in every round, which is a skill that becomes more natural the more you look at those charts. So these are some of the ways in which practice-based rounds can be a valuable way to design a game, even if it may not seem as rich as adaptive leveling.

Adaptive Leveling

Creating distinct levels within a game, which present qualitatively different actions or skills, is another important tool in a game designer's toolbox.

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Commercial games do this all the time to keep players engaged and challenged, but in a learning game, that progression needs to map to a logical sequence of skills that build on each other, and the pace becomes more important for students at different starting skill levels. *Beetle Breeders* was designed with a leveling system that takes students through a series of increasingly difficult inheritance patterns, adds dihybrid crosses into the mix at the appropriate point, and requires multiple generations of crosses as part of each of those difficulty levels. Within a level, the orders to be filled are of the same challenge type and difficulty, but players must complete a certain number of them before they are deemed ready to move on. This means that if players are having trouble filling the three orders necessary to complete level 1, they will stay on level 1 for longer than players who already understand complete dominant traits. Those players who need more practice will be able to spend time on those level 1 orders, only moving on when they seem to have mastered the concept.

In our UbiqBio pilot study, we saw that both time spent and level achieved ultimately correlated with success in class. In *Beetle Breeders*, the leveling system meant that early success in the game triggered more difficult concepts, which extended student learning. Players delved deeper, spending more time and more effort to ultimately engage more deeply with the content, which led to improved results on a postgame assessment (Perry & Klopfer, 2014).

Beetle Breeders bases its progression rules simply on the number of orders completed, but it is certainly possible to have more sophisticated algorithms to determine whether players are ready to move up. This could include factors such as how many orders they have successfully filled in a row, or details on specific mistakes they may be making. There have even been attempts in games to program complex AI that will guide students on a path through the game that has been determined to be the exact right one for them. The type of adaptive leveling with more player agency that we describe, however, in which players choose what to work on, within a "smart" framework of challenges provided, can in fact be more useful for students and certainly less resource intensive.

Comparison

Adaptive leveling necessitates that additional game mechanics be built into the games, and it means curriculum designers need to design the

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sequencing pattern and guidelines. All of this requires more development time, user testing, and tweaking, which increases the scope over a game that uses practice-based rounds. Nonetheless, it adds value in terms of educational content packed into one game, which is a plus for teachers choosing their curriculum, and it adds to the ways in which games can make connections across levels and even outside the game to other concepts. Keeping students challenged, with just the right amount of difficulty, means they will be more engaged and stick with the game for longer. Both can lead to more exposure to the content, deeper learning, and memories of the game experience that stick and are then carried through to other aspects of players' lives.

The Codesign Process

The Principle of Codesigning with Educators
There are many ways to involve practicing teachers throughout the game design and curriculum development process. Doing this ensures that the content and premise are relevant, and that the surrounding curriculum is effective and usable.

When applied	*When not applied*
The collaboration of a game designer and a current teacher means that expertise in multiple areas is brought to the project. Games are more likely to address standards that are a real need for teachers, and appeal to students in the target grade level. In addition, the curriculum developed is more likely to feel accessible to other teachers and to fit easily into a realistic classroom setting.	Game designers working in isolation may have educated guesses at what content should be covered and how best to design curriculum, but without frequent input from practicing teachers we often end up with a disconnect. The final product may prove tricky to implement in a real classroom, and the game may unknowingly promote misconceptions that we want to fight against. These issues can then emerge later in the testing process when it's more difficult to make changes to the project.

One key to a successful creative project is bringing together the right team members. We wouldn't expect a biology teacher to be able to design a great

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game, and similarly we don't expect game designers to know the nuances of teaching biology. In our experience across various projects, bringing these two areas of expertise together results in products that are both good games and good learning. We've found one effective way to do this is to collaborate with practicing teachers who join the team as consultants. There are many benefits to this model, and the UbiqBio games are a good example of our collaborative process.

Brainstorming Phase

We find it helpful to involve our teacher partners at the earliest brainstorming phase, when we are deciding the topic of a game. Teachers know best what content is covered in their standards and how much time out of the school year is spent on that unit. More importantly, they have insight into which topics are already taught well, are rife with quality resources, and are easy for students to learn. Those are not the topics we want to be covering in a new game, so we look for the challenge areas, where teachers say their students struggle with the content and need more personalized or in-depth ways to get at a concept. In planning for *Beetle Breeders*, although there are a lot of teaching materials about genetics, teachers said it was hard to give students opportunities to practice breeding in a hands-on way. So we decided that a simulation-based game with the ability to experiment with a creature's traits would be a unique experience for genetics students.

Teachers not only bring their content knowledge to bear, but also are valuable experts on the habits and preferences of their students. When we begin brainstorming game types or narrative premises, teachers provide useful feedback on whether an idea is age appropriate for their grade level, whether it's too hokey, or whether it's something they can see students in their classes latching on to. And of course, these teachers don't have to be omniscient about their students' likes and dislikes because they can easily ask the experts—the students themselves. While designing our *Invasion of the Beasties* game, there was some debate about who the characters should be—zombies? vampires? These were some of the popular characters in youth media at the time. But teachers chatted with students, some of whom thought zombies were played out, and others who had negative associations with those mainstream media icons. So in the end, we stayed away from those trends and stuck with monsters, which seemed more timeless and universally appealing.

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Design and Testing Phase

During the design phase, we periodically show mockups and prototypes to our teacher consultants to get their feedback. This provides an opportunity to correct any inaccurate content, and it also opens up deep discussions about student misconceptions. Sometimes games accidentally reinforce a misconception rather than dispelling it, and teachers who deal with those misconceptions every year are quick to point out those cases. While experimenting with game mechanics for *Island Hoppers*, the game about natural selection, we had to choose whether the action taken was changing the population in some way, changing individual traits, or changing the environment. Teachers described one of the most challenging misconceptions to combat, which is the idea that an animal can change its traits because it wants to, simply by willing its fur to grow longer, for example. One goal of the game was to make it clear that this is not possible, that no individual can change their DNA and therefore their phenotype. So we realized we needed to stay away from any agency in changing bunny traits, and put the emphasis instead on the changes in the environment. Letting students adjust the climate of the region, making the island warmer or colder, still gave them agency but kept it one step removed from the misconception we were worried about. Making the island colder and then advancing many generations would mean short-haired bunnies froze to death more often and long-haired bunnies reproduced more often, resulting in more long-haired bunnies in the population. This put the focus on the relationship between the environmental condition and the population's traits, which was at the center of the learning objectives.

Rapid prototyping and frequent user testing is a technique we employ as much as possible. Working with teachers who have their own biology classes and were enthusiastic about the project meant that we had ready-made testing groups. It was easy to visit their classes and try out ideas with their students, or even come after school and do informal interviews or small focus groups, because they were involved in the process and wanted to see things in action for themselves. Finding students in the target demographic and scheduling time with them is not always easy, so teacher consultants can help support those efforts.

Curriculum and Implementation

As discussed in previous chapters, the connections between a learning game and the rest of the curriculum is a key factor in the effectiveness of

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resonant games. A standalone game with no facilitated reflection on the skills or content or what they mean can't be expected to have a great impact on student learning. The UbiqBio games all had a suggested sequence for the unit's curriculum, with companion materials designed to help students take concepts in the games further and facilitate transfer to other relevant contexts. For example, the *Island Hoppers* curriculum included activities directly related to the game content, challenging students to think of additional bunny traits and their potential selection pressures. It also related the concept of natural selection to other species via a nondigital simulation of birds. In this activity, students take on the role of birds with different beak shapes as represented by plastic forks, spoons, and knives. They physically try to pick up marshmallows, which represent their food source, with their beaks. Some beak shapes are better suited to this task, and those birds flourish while others tend to starve to death. In this activity, students found out experientially which birds were more likely to live and die, and they could draw parallels to relationships they had explored in the digital game. Creating the bridge curriculum such as the beak-marshmallow simulation, and sequencing the activities, was one of the main responsibilities of our teacher consultants. They were experienced with integrating technology into their curriculum and had a repertoire of tried-and-true activities to choose from for these lessons. For these reasons, they were particularly well qualified to help design a curriculum that would help the UbiqBio games resonate in multiple ways with students.

Once the games and curriculum were ready, the next step was to begin rolling out the offering to teachers participating in our study. For this project, it was a small number of local teachers, but in other resonant game projects there could be wide-scale outreach and implementation. In either case, hearing the voices of fellow teachers and knowing that the game and other activities had been used in real classrooms made the project more credible and feel more accessible to teachers who might otherwise have been reluctant to try a mobile game with their students. In this way, teacher consultants help create the product, but they also help generate interest and adoption.

When Not to Listen

After detailing the myriad ways in which teachers can contribute to a learning game and complement the skills of a game designer, we should also

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note that at times, it's important to disagree with their perspective and even their pedagogy. When designing resonant games, we do want the game to be feasible to implement and fit within the existing constraints of the classroom. But only to a certain degree, because we are also trying to move the needle on innovative pedagogies such as student agency and constructionism, which often don't fit easily in a traditional classroom setting. In addition, digital games as part of formal education is still a new idea for many people, and this includes students themselves. Initial feedback and observations may indicate that students aren't comfortable with certain elements or don't easily engage in reflection activities. But if teachers come back and say this didn't resonate with my students, sometimes we don't want to dial it back but would rather keep it up to give everyone involved a chance to experience a new way of learning. This is the dance of the resonant game designer, who must take into account feedback from all team members to determine when an experience needs to be familiar and when it needs to challenge expectations.

Integration into Life and School

The goal of our ubiq games is to infuse learning experiences into students' lives, both inside and outside school, in a way that is motivating and engaging. The games do this by using devices and game-play styles that students are already comfortable with and that fit easily into their daily routines. This may look different for different students—when they play and how much they play at a time is completely up to them. The following is an example of one way in which students may experience this genre of game.

Thalia is a ninth grader on her way home after school and volleyball practice. She's tired after a long day and not looking forward to the pile of boring homework she is supposed to do, so she's thinking about skipping it. She gets on the bus, sits down, and takes out her smartphone. She puts in her earbuds and turns on her current favorite music. She sends a few texts and checks Facebook. Then she switches to the web browser and navigates to a game called *Invasion of the Beasties*. In this game she has to genetically engineer a monster so it will be able to defeat the evil enemies. Thalia likes this game because it has quirky characters with funny pictures, and it's fun to advance through the levels. Her teacher has

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assigned everyone in her intro biology class to play the game, but Thalia doesn't think it feels like school. It's obviously about mRNA—there are nucleotides and amino acids—but it's like a puzzle you have to figure out, and she wants to see if she can beat the game before her friends do. Plus she's always on her phone anyway, and she can fit this in on the bus and between classes. Thalia has played five rounds when it's almost time to get off the bus, so she puts her phone away, knowing that the game has saved her progress so she can pick up where she left off later tonight.

Playing during interstitial moments of the day—on the bus, waiting in line, between classes—is one of the primary ways in which designers envisioned ubiq games could be used. But this is by no means the only way, and even within this model is a great deal of flexibility. Some students may choose to sit down and play for a longer chunk of time, perhaps as the first piece of homework they decide to work on, or perhaps as the last thing of the day as they get into bed. Some students play primarily during school hours, even sometimes sneaking their devices into school (Klopfer et al., 2012) or secretly playing during other classes. While not endorsed, this behavior does speak to the appeal of the games and format! Some students end up working the game into a routine, playing at the same time of day each day, such as when they're waiting for the bus; while others have more varied schedule, with work and afterschool activities, and find it more convenient to play at different times each day. Students can play on their own, or while sitting next to friends who are also playing; they can text their friends about what level they're on or wait until the next day in class to compare strategies and ask for help. Some students even share the game with other family members by playing at the dinner table or getting their siblings to help with the tricky levels. The takeaway here is that regardless of how students played, most were able to find ways to integrate the game into the fabric of their lives. Adding a different kind of schoolwork didn't mean they had to find time to get to the computer lab or rearrange their schedules. The ability for students to make a game their own and control how much and when they play contributes to their ownership and adoption of the game. This, in turn, enables the game to become deeply embedded in their lives and to provide a new kind of ubiquitous learning experience.

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Games that Fit into Everyday Life

The Principle of Integrating into Everyday Life
Because fitting a game into students' busy lives can be a challenge, the game mechanics and format must be thoughtfully designed to work within the constraints of either in-school or out-of-school time.

When applied	*When not applied*
Game designers who carefully consider where and when their game should be played, plus what variations there may be, will end up with a game that is much more likely to be adopted and embedded into players' lives. They will not only have access and time to play the game but can really embrace it, letting the game become part of the fabric of their lives for a time.	Game designers who don't think about where and when the game will be played, or who assume the game will fit into any context, are more likely to end up with a game that doesn't get a lot of traction, even if the game itself is great. If players can't find enough time to play, or have trouble accessing the game from places they want to play, they won't end up getting into it even if it initially seems appealing.

As the examples above show, we have seen students integrate ubiq games into their daily lives in many ways. The fact that students do this in so many different ways (when, where, how long, how often, with whom, etc.) shows that the merit to this model of game play. We also must acknowledge that the design of the games, both the format and the mechanics, contribute to the flexibility and personalizability of the genre. Through the process of designing, building, and researching the four UbiqBio games, along with *Weatherlings* and *Palmagotchi*, we have extrapolated some common design principles that together make up the principle of integrating games within students' current daily lives.

• **Short but meaningful experiences**: Game play is split up into bite-sized chunks, where each chunk lets players do something involving the science concepts, such as breeding a generation or two of beetles, or balancing a food web. Players must do some thinking to accomplish something in each chunk, but they can decide for themselves how much to play in one sitting.

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• **Ability to easily resume play**: Each new challenge or level doesn't require a lot of exploration or startup time. There are differences that keep it fresh, but each one is familiar enough that players can pick it up and keep going even if they have only a few minutes.
• **Continuous saving of progress**: Player actions should be saved automatically and frequently so that when players get interrupted by other things in their lives and have to put the game away, they will know they can pick up where they left off with a smooth transition to the next play session.
• **Engaging leveling system**: Play sequences in the game build in content, challenge, or simply number, leaving players wanting more and looking forward to the next time they can pick up the game. Mechanics are engaging enough that students think about their strategies even while not playing, and are motivated to talk about them with friends.
• **Ability to reference game elements**: Players can easily talk about the game together because the elements of the game, such as characters, levels, or tools, are clearly labeled and memorable or intuitive. This makes it easy for players to quickly ask each other questions about feet stickiness or the universal genetic code without having to look back at the game or check what they were working on.
• **Social experience**: Game mechanics that require interaction with another player, either synchronous or asynchronous, can benefit both learning and engagement. Players are encouraged to discuss concepts together to work out the challenge, or are motivated to beat their friends by taking their skills to a higher level. Players expect a lot of social interaction on their mobile devices, especially outside the classroom, so opportunities for collaboration can boost appeal as well as impact.
• **Fun and appealing**: A good casual game should appeal to many types of players, and studies have shown that our ubiq games are enjoyed by both boys and girls equally (Klopfer, 2008; Klopfer et al., 2012; Perry & Klopfer, 2014). As games that are played on students' own mobile devices, they are inherently competing with other games and apps students have on their phones. All the above design principles help ubiq games to be playable and engaging, but the number one way to attract players is to make the game narrative and mechanics intrinsically fun!

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This complement of game design factors, when cleanly integrated into a game experience and used wisely, can lead to the variety of outcomes presented at the beginning of this chapter, which make the ubiq games experience unique. They ensure that a game works well and is easily accessible on a device that students already use. They enable students to play in short, frequent bursts, often during interstitial moments of their day. And they allow students to become deeply engaged with a game and with each other. It should be noted, however, that these particular factors need not function as a checklist for game designers, nor should they be considered an exhaustive list. A good ubiquitous game or a good resonant game need not incorporate every factor to be successful. Rather, this may be considered a pool of ideas to start with and draw from as you design games with goals similar to our ubiquitous games.

Games that Fit into the Classroom

While one of the main goals of ubiquitous games is to integrate smoothly into students' lives, to be used well, they must also integrate smoothly into the classroom and into teachers' pedagogical practices. This means supporting and extending existing curriculum, providing the teacher with information on how students are doing, and giving teachers the flexibility to implement the game as they see fit. The following is an example that illustrates the teacher experience of ubiq games.

Ms. Geary is a high school biology teacher finishing up some grading and getting ready to head home. The quizzes she's grading are tedious, so for a quick break she opens up the teacher website for *Invasion of the Beasties*, which she has assigned her students to play. She checks to see who has the highest score today, and while the usual students who reliably do their homework are indeed in the top five, she's pleasantly surprised to also see Thalia listed there. Ms. Geary has always seen Thalia as a perfectly capable student, but it's been hard to get her engaged in any of the biology content she's taught this year. Looking at the stats, she is happy to see that Thalia has been playing about thirty minutes each day this week, and considering the high level she has reached, Ms. Geary knows that Thalia is understanding the topic of mRNA and the translation process. If she wasn't able to use the universal genetic code, she wouldn't have earned such a high score in the game, so the data are very promising.

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Ms. Geary closes the page and reminds herself to congratulate Thalia in the morning and make an effort to encourage her to share with other students the strategies she's developing. While these mobile biology games are fun and engaging for many students, one of the most valuable things Ms. Geary has found is the way they also stimulate content-rich, authentic conversations.

Aligning with Standards and Curriculum

As with any piece of curriculum, for ubiq games to be used by teachers, they must be aligned with standards and fit within a typical unit. This doesn't mean they have to use traditional pedagogy or approach the topic in the same way teachers always do, but they must have clear connections to what teachers already cover. For deep learning, it's important that these connections be not only to content standards, but also to process-oriented skills, STEM practices, and even soft skills. Without that stated explicitly, teachers could rarely make time in their packed curriculum to cover something additional. As part of being aligned to existing curriculum, the game should have a clear progression in terms of the content level, subtopics, or skills presented. This often takes the form of a teacher's guide they can quickly refer to, to know things like which inheritance patterns are covered in which levels of *Beetle Breeders*, or what skills are being built as information is gradually taken away in *Invasion of the Beasties*. Having this information clearly laid out helps teachers select games to use in their classrooms, and integrate them into their curriculum in meaningful ways.

Another essential piece for integrating ubiq games, and indeed any resonant game, into a classroom is supplementary materials that tie the game to the existing curriculum. The principle of making curricular connections is discussed in more detail in chapter 5, and it applies in many of the same ways here. Ubiq games are designed for students to play on their own time, and to build skills and concept understanding at their own pace. Yet, they are not designed with the goal that students will learn everything they need to independently. In our experience with resonant games and educational technology in general, the game builds a foundation, but knowledge is solidified and extended through reflection and collaboration, best facilitated by the teacher. While UbiqBio teachers' implementations varied, they

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were encouraged to have students play the game before formal instruction took place, or at least near the beginning of a unit, to allow for the sequence of game play followed by reflection and further instruction. As described in chapter 3, the principle of preparing for future learning tells us that a valuable function of resonant games is building a foundation of understanding for students and teachers to build on in this way. Some superstar teachers do this naturally and are able to come up with their own bridge activities and companion materials, but it would be an unreasonable expectation for all teachers to do that well on their own. For this reason, a key piece of the UbiqBio offering was the curriculum and activities, designed by our teacher consultants, that went with the games. These activities provided some context for teachers to dig deeper into what students were doing in the game, explaining more about the genetics and supplying useful terms. They also enabled teachers to generalize more abstract concepts from specific in-game contexts to examples involving other species or how mRNA

The Principle of Connecting Data to Practice
To effectively provide teachers with data, designers need to carefully plan what data should be collected, coordinate that with the game design, and support teachers in how to use that information to inform their classroom practice.

When applied	*When not applied*
The right amount and the right kind of student data, displayed in an accessible teacher dashboard, will be welcomed by teachers. With training or resources for how to make sense of that data and how to use it, teachers will be able to check the dashboard regularly, then focus their class discussions or adapt their labs and activities according to the students' needs. This results in a game that is well connected with the rest of the curriculum and learning experiences in the classroom.	Too often when data are provided to teachers, they are either superficial or overly complex, either of which results in little information on student learning. Other times, even with useful data displayed, teachers new to game-based learning may not be familiar with how to interpret the data or what they can do to connect classroom activities to game-play experiences. This results in a game experience that is disconnected from the rest of the curriculum—a missed opportunity to engage students and solidify learning.

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functions in other biological processes. This meant that students were reflecting on what they had learned in the game and applying it to new situations, thereby engaging in transfer—one of the most challenging processes in education.

In addition to concrete activities included in the supplementary materials, there was time built in for class discussion, and prompts to scaffold that time for teachers. Whether or not a game has social interaction built into the game play, the social experience that exists outside the game can be equally important. In UbiqBio, many teachers were surprised at how much collaboration they saw among students discussing strategies, asking for and giving help. These interactions involved discussing biology concepts and teaching others, which can be hard to bring about in a traditional classroom. This shows just how important face-to-face class time can be, even for a game played entirely outside of class.

Connecting Data to Practice

The UbiqBio games came with another important tool—the teacher dashboard, a website teachers used to track student progress (figure 6.7). The data-logging system collects player information which is then displayed to teachers so they can easily track participation. Along with game data, such as score and level, the games also log other types of data that describe play patterns, such as how long players spend in each area of the game, and how many times they log in. In addition, designers can collect data that will reflect how well students understand the material and therefore help teachers assess their progress. These data are displayed in the teacher dashboard to let teachers quickly see how much their students are playing, and what they are getting out of their play time.

Designing a teacher dashboard to convey information about student participation and progress in a game should be taken seriously. To be successful, it should be considered a major piece of the project and should have work put into it throughout the game design process, rather than as an afterthought. One reason for this is that the data collection needs to be built into the game and must be woven together with the game's learning objectives and mechanics. Considerations around what to collect and what is meaningful are likely to affect the specifics of those game mechanics and the user interface, and for this reason, neither one can really be completed

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Login	Name	Current Level	Current Balance
player_1	Maria	1	$100
player_2	John	4	$518
player_3	Hector	6	$1,104
player_4	Shawna	1	$100
player_5	Angel	2	$149
player_6	Kai	6	$1,067
player_7	Thalia	2	$118

Figure 6.7
Beetle Breeders teacher dashboard sample

before the other (Groff et al., 2015). In addition, the teacher dashboard won't be used or useful unless it provides meaningful information to teachers in a convenient format, and the best way to ensure those factors is to continually get feedback from teachers. This can mean running mockups by the teacher consultants, or including the teacher dashboard in early prototype testing. While teachers feel it is essential to have data on their students' game play, they don't want to be inundated with information they see as extraneous.

Aside from the design of the teacher dashboard, the other tricky piece of integrating it into a game-based offering is working with teachers on how to use those data. Teacher feedback and user testing can tell you a lot about what data teachers want and how they are likely to use those data. But for a resonant game to have the most impact it can, existing habits may not be enough. This is another case where providing innovative tools can help move the needle on what teachers are doing. Providing data teachers may not have thought to ask for, along with training on how they can use those data to inform their classroom practices, can deepen the impact of the learning experience for students while also giving teachers new pedagogical tools they may not have been comfortable with before.

During the UbiqBio project, we found various ways in which teachers were quite comfortable using the teacher dashboard. They periodically checked the level each student had gotten up to, or the amount of time each student had played, usually depending on the metric they had assigned students for game play, to see whether the student had met requirements. Teachers who felt their students would benefit from competition would

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even post the daily high scores to generate excitement. They also used the basic data in multiple ways to determine which students they needed to catch up or check in with. For example, if they noticed a student had few points but had played a lot, they might guess that the student was struggling with the content. If they noticed a student had few points but also hadn't played for very long, however, they might check in to see whether the student was having technical difficulty or just hadn't bothered to play yet. These strategies felt accessible and were easy for teachers to incorporate into their formative assessment and teaching plans.

There were other dashboard uses that fewer teachers tried, or that teachers mentioned as being useful in theory but that they didn't do very often. For example, purposely connecting students to facilitate collaboration. If they noticed a student who had many points or had played through high levels, that student could be encouraged to help out other students who might be struggling in that same game. It takes a little more work to identify what students are struggling with, match them up, and scaffold how they can help each other, which is why most teachers were more likely to let collaboration happen organically. Another more nuanced way to use the teacher dashboard would be to map specific game actions to specific learning objectives. With relevant data provided, a teacher could notice which level a student may have been stuck on for a couple days, or even which genetic crosses the student had been attempting unsuccessfully while working on a certain contract. The teacher could then refer to the teacher's guide to confirm which inheritance pattern that level focused on and check to see if multiple students in the class were having trouble with, for example, dihybrid crosses involving codominance. Armed with this information, teachers could adjust their practice by pairing these students up with students who already had strong breeding skills in codominance, or by pairing students with unique strategies to generate discussion. They could use class time to review that inheritance pattern or explain it further, and they could provide additional activities or resources outside the game to get at that concept from a different angle. These are some of the ways in which teachers can effectively use student data to inform their teaching practice, but it won't necessarily happen spontaneously. On the contrary, this type of opportunity must be thoughtfully designed into the game and tools, and teachers must be provided with resources, training, and examples of how best to integrate those tools into their classroom. This process

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takes work from the game and curriculum designers, as well as the teachers, but it pays off by resulting in a more meaningful game experience for all involved.

Flexibility of Use

In many of our resonant game projects, we emphasize the ability for teachers to be able to implement the game however they see it working best in their classrooms. Schools, classes, and students all have their own character and their own constraints, so for a game to be successful, it must be allowed to be molded to fit the context. We also emphasize the need for teacher resources—curriculum materials, reference guides, and professional development opportunities—as a way to support teachers. It must therefore be noted that in designing the game, its implementation model, and the supporting materials, designers must strike a balance between offering advice on how to best implement the game and letting teachers figure out for themselves what works best.

The UbiqBio games serve as a clear example of this balance. With four separate games that form one larger experience, there was room for teachers to try things and improve on their implementations. Each individual game was small enough that even with the supplementary materials, it felt accessible to teachers—it was manageable to fit into their curriculum, and they could wrap their minds around how to adapt the game to their needs. This was more doable with UbiqBio than with a bigger, long-form game like *Radix*, which took more commitment and investment up front.

The teachers that implemented the UbiqBio games as part of our pilot study did have certain elements in common in their approaches. They all introduced the game in class, assigned it in some way, let students play on their own time, and conducted some amount of the supplementary curriculum during class time. Within these approaches, however, were many differences.

- **Use**: The function of the game within the curricular unit was one of the main choices teachers had to make. Sometimes it was used before teaching the content, in accordance with the preparation for future learning approach. Other times it was used during the unit, especially with a game that has a content progression such as *Beetle Breeders*; teachers could assign relevant levels as they taught those inheritance patterns. The games were

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also used after a unit, either as additional practice on things like Punnett squares, or as review of a concept taught earlier in the year, which many teachers did with food webs. Selecting the timing and function of a learning game is an important decision that can affect many other aspects of a teacher's implementation.

- **Requirements**: Most teachers gave some type of requirement for students playing each game. For example, play to level 10 by the end of the week, or play for at least twenty minutes a day. These were metrics they could track and in some cases use to assign a homework grade. Other times they made the game optional as an extra credit assignment. Overall, teachers were pleasantly surprised with how much students played beyond the specified requirements.
- **Competition**: Some teachers found competition to be a useful tool to generate excitement in the classroom and to motivate students to keep playing. They would share high score lists and offer small prizes or recognition for top players according to various metrics. Other teachers felt their students would not react well to that and chose to keep results more private or to promote more collaboration instead. This element can work well in either direction and must be decided by taking into account students' personalities.
- **Bridge Curriculum**: The curriculum provided was divided into required activities, which designers had determined to be the highest priority materials to make connections with the game content, and optional activities, which added exposure or extended the topic. Teachers were free to use varying amounts of the optional materials, which they appreciated. They were able to pick and choose according to which areas they already had preferred activities for, and which topics they thought could be improved by new lesson plans.

Of course, many more choices than these go into the implementation of any game, and other aspects are discussed in other chapters of this book. These examples give a sense of the types of differences in teachers' implementations, from pedagogical approaches to logistical details. You should consider the similarities and differences you anticipate in the implementation of your resonant game throughout the design process, all the way through to the presentation of teacher materials. A game experience will feel most personal and meaningful by providing the right amount of scaffolding while also leaving room for teacher autonomy.

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Conclusion

Designing a good resonant game is largely about finding ways for the game to become a cultural artifact, an experience that gets willingly adopted by your users and incorporated into their lives. There are a variety of pathways to this outcome, and ubiq games arrive there a bit differently than games like *Radix* and *Vanished*. Ubiq games are short form and have a narrower scope of content in order to fit the casual mobile game format. Their play experiences are bite sized instead of immersive. In a sense they are leaner and scrappier, infiltrating players' lives through the cracks. Yet these games also have key elements in common with the other resonant games we have discussed. They provide authentic experiences with the educational content, with hooks to make connections to other ideas and other aspects of students' lives. While in a literal sense a play session can be completed in five or ten minutes, experientially, the learning doesn't stop there. Like other, longer-form games, companion activities or curriculum only strengthen the game's impact, with each element building on the others to really resonate with players.

Like the everyday places you visit frequently, ubiq games may not seem like a major part of a learning experience the first time you open the game. But like those familiar locations, the more you visit and spend even small amounts of time there, the more ubiq games start to affect you and become a part of who you are. The unique characteristic of well-designed ubiq games is how they fit into players' lives, and stay in players' lives—namely by meeting players where they are, with a format that works on devices they already have and use regularly. Ubiq games can deliver content in accessible ways and can be a great fit for certain audiences and settings, whether played as the core learning experience or even attached to another, larger game. For these reasons, ubiq games are a pragmatic format with high potential to resonate with students.

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7 Doorway to Games

Because everybody knows you're supposed to save. Yet, only 47% of Americans have $400 in a savings account right now to cover an emergency.
—Nick Maynard, SVP, Commonwealth

"Game" Design and "game" Design

This is not really a chapter about game design. But it is definitely about Game design. Gee (2008) has sought to distinguish the "game" (with a little *g*), which is the software that comes in a box (or more likely delivered to your browser at this point), from the "Game" (with a big *G*) which also includes all the social and contextual surroundings for the game. The success of a Game, marked by both its effect on individuals and the scale it reaches, is heavily influenced by the entire Game ecosystem, not just the software itself. As designers, we must pay attention to the software, of course, but we also must carefully design the social and contextual surroundings.

Designing and creating these surroundings requires a different set of skills than designing the software. There isn't a simple formula for creating this context. Instead, it requires understanding who the particular audience is, what their strengths and challenges are, why and where they would be playing the game, and how they transfer that learning. That is all very particular expertise. In school-based projects we might rely on teachers and school administrators to help provide that context. But other venues and audiences demand additional expertise. And this requires partnerships.

All the work we do requires partnerships. Throughout this book you've seen examples of partners we have sought. There have been schools, museums, content experts, educators, developers, production partners, and

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more. Most of our work focuses on middle and high school kids and STEM learning. So we have a good and growing network of great partners in that space. But we delve outside this content area and demographic when there are interesting opportunities.

What this chapter is about is the partnerships required to design, distribute, and implement games that have an impact. These partnerships include game designers and pedagogical experts, of course, but also content specialists, foundations and other funders, distribution channels, facilitators, consumers, and potentially many others. Finding great partners and making those partnerships work is an art in and of itself.

In this chapter we cover the following principles related to partnerships creating resonant Games.

- Fostering communities of practice
- Working with the right partners
- Applying skills to daily life
- Facilitating lifelong learning

Past Partnerships

One example of partnership is in the English language-learning game *Xenos* (figure 7.1), which we worked on for quite some time in the Education Arcade. In the early 2000s we were approached by colleagues in the Hewlett Foundation who were taking over the development of an English language-learning experience. The experience was to be for speakers of Mandarin (and later Spanish) who wanted to learn English. They needed design help to make this game work. Through a grant, we took over the design on the project, and in the ensuing years we worked with language and culture experts, development studios, foundations, and international partners to develop the game. In fact, the effort grew so much that the game formed the basis of a nonprofit company that we spun off called the Learning Games Network (LGN).

One of the interesting challenges the LGN faced in implementing the game was how to reach the adult audience seeking this type of experience. While the language-learning market is fairly substantial, it primarily supplies products for affluent business travelers seeking language skills. *Xenos* instead targets low-income adults, often recent immigrants, to provide them with English language skills. So with additional foundation funding,

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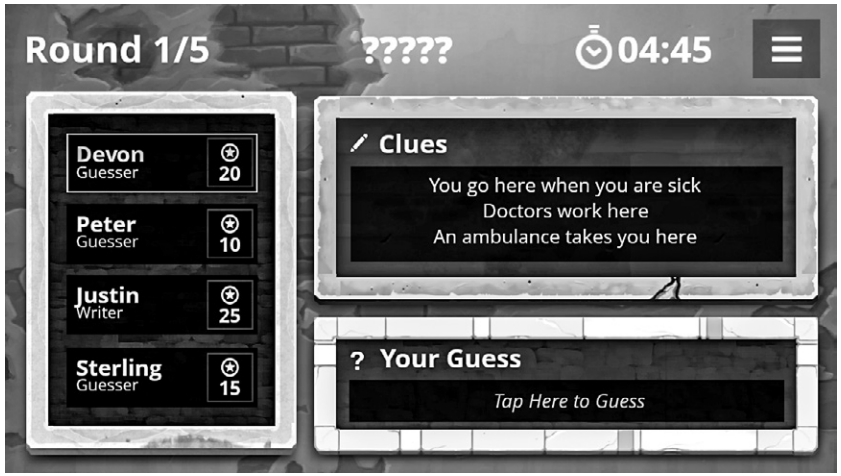

Figure 7.1
One of the minigames in *Xenos*, an English language-learning game

LGN created partnerships with public libraries to run sessions for adults. LGN also partnered with BJs Wholesale Club to provide training to some of its employees. Neither of these was about "game" design. But they were about "Game" design. They were about designing the surrounding context and audience to make the experience successful. They were about creating communities of practice to foster learning.

Communities of practice (Wenger, 1998) are groups of individuals doing things together and interested in similar things. Obvious examples would be a photography club or a baseball team. They can also be a group of coworkers, or less formal groups as we see today in maker spaces. The defining elements of a community of practice are the domain, community, and practice. The domain is the topic or area of interest to the community. The community is the collection of people and the connections they make to each other. And the practices are what they actual do in the community. It is important to note that communities of practice are not homogenous, and the participation of individuals is not consistent. Different people can make unique contributions, and individuals can vary their level of participation, either moving from the periphery to the center over time, or even varying their position intentionally over time.

Reaching adult learners effectively means either tapping into existing communities of practice or creating new ones. In the case of *Xenos* at BJs,

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LGN was able to connect to existing communities of practice, the workers. Nonetheless, that community was not established for the purpose of language learning. That was not the domain of the community, nor one of the existing community practices. So *Xenos* could leverage an existing community, but it needed to insert a new domain and a new set of community practices. Considering ways to make those practices shared across the community requires some careful engineering. The new practices need to be connected to the existing values and activities.

Similarly, creating a new community of practice, like through the public libraries, also requires understanding the nature of the community that you are trying to construct. Are there ways of recruiting from other communities? How will the members of the community be introduced and supported? People in the community must become invested in the outcome and appreciate the need for the community itself.

The Principle of Fostering Communities of Practice
Communities of practice for players, educators, and even designers can greatly benefit the process but must be supported intentionally.

When applied	*When not applied*
Resonant games are built by and used by communities. The communities required to create resonant games includes game designers, content experts, artists, players, educators, and marketers. Together this community works to understand the people who will be playing the game and how to reach them. But resonant games are also played in communities, groups of people who are either directly interacting through the game or interacting outside the game. Fostering that community is critical to making the game experience work.	Resonant games cannot be built on narrow expertise. An expert in only the content area or only in game design will wind up with a game that is missing key characteristics, or will fail to meet the needs of the community. Games that are designed only for individuals will feel isolating or will fail to spread.

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For *Xenos*, the community was a community of learners. They might come together at the library or just happen to work at the same place and have aligned goals. The game would leverage that community, and through these partnerships hopefully even strengthen that community. Such community is important in all games. Look at even the most successful of games—*Minecraft*. Part of what makes the game great isn't just the game play, but the community of personalities large and small participating in the game in various ways from community mods to YouTube stars.

But the community aspect is even more important in a marginalized population. You need to be able to reach this audience, have their trust, and help them support each other. That makes building a community for a game like *Xenos* even harder.

Problematic Partnerships

There are a lot of people and organizations out there who believe that games are the pathway to success. In some ways, this is fantastic. The power of games to affect how people think and act is finally being noticed and leveraged for many positive purposes. But as you may see from the number of principles that we outline in this book, there isn't a simple pathway to designing effective games (and certainly not to designing effective Games). Over time we have developed some red flag indicators for partners who see games as the current fad in capturing an audience versus partners who appreciate the richness and complexities of games and game development.

One of those red flags is a conversation that begins with a sentence like, "I'm interested in using games to make kids do X by making it fun." There are at least two big problems with this approach. First, we don't want to force anyone to do anything. Games are about connecting to players and meeting them where they are at. They aren't about coercion. Second, the goal isn't to make things fun but rather to leverage what is fun about particular topics, and to amplify that through game play. Instead of coming up with a predefined pathway, partners who appreciate these differences come to us with challenges, goals, and even ideas about what they think is fun about the particular topic.

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Another red flag arises in conversations with prospective partners when we talk about the complexity and resources required to develop one or more games. These conversations begin with, "Can't you just …" and then usually are completed by something like "reskin *Angry Birds*" or "reskin *Minecraft*" or whatever the game du jour is. They also seek to reduce the required resources by using the same mechanics to model different processes and systems.

The problem with this approach is that it merely creates chocolate-covered broccoli. The learning and outcomes aren't tied in any way to the game dynamics. And this simply is not effective in promoting learning or change in any way. This isn't to say that inspiration from other games and genres is negative—just the opposite. Thoughtful partners know what games are out there, how they work, and what people find compelling about them. And those ideas can and should be leveraged, when they can be mined for connections to the systems, processes, and goals of interest.

The Principle of Working with the Right Partners
Game projects benefit from partners that fit the project's goals and provide complementary expertise.

When applied	*When not applied*
Resonant games require not just working with partners, but working with the right partners. That means partners that have complementary skills and aligned goals. Complementary skills optimize work and ensure that all of the requisite pieces of the resonant game can be created. Aligned goals mean that the product can have a coherent vision.	Choosing the wrong partners can take many forms. Sometimes that means loading up on some skills and missing others. That produces a lopsided game or a game that doesn't connect in the right way with the audience. Misaligned goals can be even more problematic: with teams working at odds with each other, the product may never be finished, or at best may come out as a Franken-game, just a set of disparate pieces connected with each other.

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Many novices assume that the fun in games comes from expensive 3D graphics, intricate details and simulations, and production value. While some popular games do fit those criteria, many games with simple graphics and dynamics offer compelling game play and become big hits. Knowledgeable partners appreciate that there are many styles of games out there with different appeal to different audiences, and success comes from finding the right match, not simply replicating the fanciest production.

Most importantly, good partners do their homework to learn as much as they can about the endeavor of game development, and in turn they learn where they can contribute and where they need input from partners. These criteria apply to all partners, including designers and developers like ourselves, as well as organizations seeking to align with designers and developers to make games.

The Doorway to Doorway to Dreams

So in 2007 when we received multiple requests from respected colleagues for us to take a meeting with Nick Maynard of the 501(c)(3) nonprofit Doorway to Dreams (D2D) Fund (later rebranded Commonwealth, which is how we'll refer to it here), we kept these principles of good partners in mind. One thing we did was do our homework on Commonwealth. Its mission is to "strengthen the financial opportunity and security of financially vulnerable people by discovering ideas, piloting solutions, and driving innovations to scale." As Nick said in a 2016 interview, the number of people that fit in that category is staggering, around 162 million Americans. This was a departure from many partners we had worked with before, but certainly a noble mission.

Nick and Commonwealth had certainly done their homework as well. He had played recent popular games (at the time online Flash games were the rage, filling the space that many smartphone games currently fill). He was trying to understand what made these compelling experiences. He had tightly defined his audience of financially vulnerable young adults eighteen to thirty-five, and he knew what he didn't know. This last trait is perhaps the most important. Not everyone in a game design and development project needs to be a game expert, or even particularly game savvy. They

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all need to be open minded, willing to learn, and contributing a unique set of skills. Good teams and partners are made of participants with varied skills.

As Nick relates, Commonwealth's strategy is to have several initiatives in the pipeline at all times. Back around 2006, they had noticed all the game-based initiatives in other areas. "And then our co-founder Peter Tufano started seeing simulations in the business school classroom and so forth, and we started to wonder about the application of games toward financial education."[1] And at the time, the bar was very low in financial education. Nick says there was very little innovation in the space.

> That led to this theory of change around Financial Entertainment. So [we could create] casual video games that try to focus on maybe three to five core learning objectives … but with a real hope towards directing people through that experience, to being an off-board to action-taking. In a world where the majority of financial education is a pamphlet or website full of information or, for employees, a big thick 401k pack, the offer is different. It's "here's a video game." And more people, we believe—and our research shows this—will choose a video game over a packet. … If you have the right setup, then you can connect them to all the resources that exist, like their 401k platform, or information about how to set up a savings account.

The Commonwealth theory of change that emerged was

1. Engage consumers: You have to grab their attention.
2. Cultivate financial self-efficacy and financial literacy: Then you can start to help them learn about positive financial decisions.
3. Enable initial action: And link that directly to actions that they can take.
4. Support sustained behavior: And continue those behaviors over time.
5. Realize positive economic outcomes: This ultimately leads to real economic change in the lives of individuals.

Game-Changing Games

Commonwealth's idea was fairly simple—create some casual games that engage eighteen- to thirty-five-year-olds with mechanics and concepts related to financial education, and use that as a jumping-off point into action they can take to immediately improve their financial strategy. One

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of the key distinctions about this strategy is that the game needed to be designed for both learning and action/behavior. Connecting a game to a real-world situation may seem like it should be easy. Situating a game in a real-world problem that has real consequences should be engaging. But there are potential pitfalls in this design.

The Principle of Applying Skills to Daily Life
Game features and curriculum materials work together to demonstrate authentic context and to tie game play to real-world situations.

When applied	*When not applied*
One of the great challenges of learning design is the challenge of transfer. Something that is learned in one context is difficult to apply in another context. With this in mind, resonant game designers consider the context in which the games will be applied and design to create easy transfer from the game context to the real world.	Games that are not tied to authentic context can fail to resonate with the players because they fail to see the connection and personal relevance. Even if players wind up playing the game, they will not be successful in transferring their game play to understanding that is manifest outside the game.

There is a whole genre of games for change, or impact. These are games designed not necessarily to teach something new but to change people's behaviors. The game should make them see something from a new perspective or change their actions and attitudes in some fundamental way. One recent example is *That Dragon, Cancer*, a game about a four-year-old boy with cancer. It is a game about finding hope.

Creating games that really effect change is much more challenging than it seems. The obvious perspective to take when making a game to understand the predicament of a financially challenged person, for example, is to put yourself into that person's role and have you try to get out of it. The challenge there is that rather than developing empathy, the player may instead blame the person for making poor choices. A study on the game *Spent*, a game about poverty, found exactly this (Roussos, 2015). That study found, "Any positive feelings evoked by empathy from seeing the challenges of poverty are off-set—or even outweighed—by the negative

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feelings brought on by the belief that poverty is personally controllable, which is the inevitable result of playing a poverty game which emphasizes decision-making."

The author of the game, Colleen Macklin, reflected on the design of the game (Parkin, 2016): "In a game you have complete agency, but in some life situations, people have no choice. … If a game is trying to create empathy in this way, it can back-fire spectacularly."

Similarly, just telling people the right behavior is not enough to actually change that behavior. Oftentimes people know the right behaviors but still make the wrong choices. This is inherently human. In a recent study of young children's dietary decisions, researchers taught children about healthy eating and mealtime decision making (Joseph et al., 2015). The children indeed learned that fruit was healthier than cookies, and when given a choice on a test, they were able to make the right decisions. But in real life when they were given that same choice, they reverted to preferring cookies over fruit. Knowledge is not sufficient for inducing behavior change in this case either.

So making a game that leads people to making responsible and proactive decision making about finances must involve more than understanding the perspective of people in that predicament, and it also must involve more than understanding the principles underlying such decision making. Commonwealth realized this: "Everyone was trying to push us to big game companies that did military work. And we wondered, how would 3D visualization of one's life help? We didn't feel that consumers wanted to play a game about being poor. And we certainly didn't think it should be called 'Don't Be Poor.'"

Commonwealth focused on casual games, a genre that people in their demographic were familiar with. The organization didn't have a desire to innovate in game dynamics, but preferred to use familiar dynamics to comfortably challenge people's thinking. Those interactions could be backed up by a lot of data. Commonwealth knew its audience really well. It had data from interviews, banks, research, and federal agencies. The organization knew the problems that people faced and what they could do about them.

To move the idea forward, Commonwealth held a series of brainstorming sessions with our group, the Education Arcade, in which the first idea arose. Someone proposed the idea of celebrities and celebrity culture. Nick

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recollects, "What do celebrities spend money on? Back then, game designers thought it would be fun for players if it was drugs and alcohol that ran up credit card debt. And I thought, OK. We can work with this. And that's how that piece came together to create the first game. Afterwards, the goal became to figure out the best game mechanics."

While the basic theme of the game, problematic celebrities, arose in a game jam, the development of this idea, like all Commonwealth games, was then connected back to continued testing and input from the target audience. What the players actually did, what their challenges and goals were, and how they interacted with the game were all subject to input from potential players. Commonwealth leveraged a marketing tool called Zaltman metaphor elicitation technique (Zaltman, 2001), a form of consumer research, to engage people in the process and subsequently engage with designers. This technique uses a series of images that research subjects bring and assemble with researchers along with in-depth, one-on-one interviews to elicit people's thoughts, even when those thoughts are floating just beneath the surface of consciousness. It allows researchers to better understand what people are really thinking about the ideas, rather than what people think the researchers want to hear. These images might be of spending or saving money, how to manage their lifestyle and budget, or simply images of well-managed or poorly managed finances.

The Principle of Facilitating Lifelong Learning
Considering design elements specific to lifelong learners will make the game more relevant and more accessible to players outside school.

When applied	*When not applied*
Resonant games are not just about schooling. Instead they connect with concepts and contexts that transcend school, extending to life not just outside school but beyond. They connect to ideas that will be useful for life and applied in the future as well as in the present.	Games that focus only on the immediate task at hand may produce short-term gains (e.g., the ability to recall the answer to a math problem), but those gains will be ephemeral and vanish immediately after the test. Learning from experiences that don't account for this principle is not durable.

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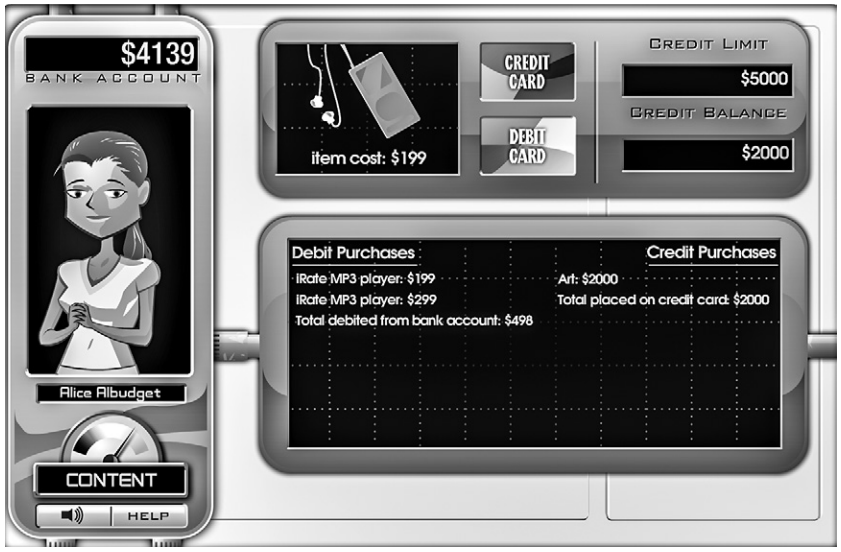

Figure 7.2
Managing the finances of Alice Albudget, the first celebrity in *Celebrity Calamity*, with the main dashboard showing how happy the celebrity is and allowing the player to review her current financial status, such as current purchases, and the use of credit and debit cards (© 2017 Commonwealth)

Once playable versions of what came to be called *Celebrity Calamity* were available, there was more research on how the games were perceived (figure 7.2). The first playables focused on players managing the finances of celebrities. The designers still needed to consider how this specific audience of adults, looking to learn and improve, would benefit from the game. As Nick explained it,

> A big part of it was that we really believe in keeping the consumer at the center of all the decisions we make. … I cannot tell you how someone else needs to be motivated to save money. But *they* can tell me how they need to be motivated. That is the best case that we could ever make for any decisions, and it's rooted in consumer preference and consumer demand.

The final version of *Celebrity Calamity* puts players in the role of assistants to famous celebrities. The players' job is to make the celebrities happy by providing them what they ask for, but also to manage their finances to make sure that they don't go bankrupt.

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The player must book appearances for the celebrity and "purchase" items that the celebrity needs. The bigger challenge comes in managing how to pay for all those things using a combination of credit and debit cards.

The purchasing phase of the game involves simply moving a character back and forth to collect money falling from the sky (a popular, simple mechanic at the time the game launched) as well as the other items that the celebrity has requested (figure 7.3). At the same time, players must avoid unnecessary purchases.

The celebrities further complicate things from time to time by making very big purchases all on their own. That is something that players need to factor in as they figure out the budget and how much debt to pay off. The game heavily emphasizes the need to pay off that credit card debt with a very high rate and provides a lot of positive reinforcement if and when that debt is paid off. Every round the player sees the current expenses, debt, and

Figure 7.3
The money and item-catching phase of *Celebrity Calamity*, when the player must catch the falling money and the designated items, seen in the top row (© 2017 Commonwealth)

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finance charges in a way that looks fairly similar to actual credit card statements (figure 7.4).

As players make their way through the game, they are given the opportunity to manage other celebrities who have more demanding needs, which results in more challenging budgeting and finances. At the bottom of each page is always a leaderboard and links to financial resources to help with real life debt.

What worked about this game dynamic was not that it made people understand that debt is bad, or that saving is good. Nick says that what made the game work was "This efficacy component. So Celebrity Calamity moved the needle on self-confidence for folks with very low financial self-esteem. But the sense that this celebrity is making crazy purchases, and I get to bring control to that? That was empowering." *Celebrity Calamity* generated over 100,000 plays in the first three years that it was launched, with frequent repeat traffic. Surveys also showed that it was reaching its target audience, with over 80 percent of game play from low- and middle-income players.

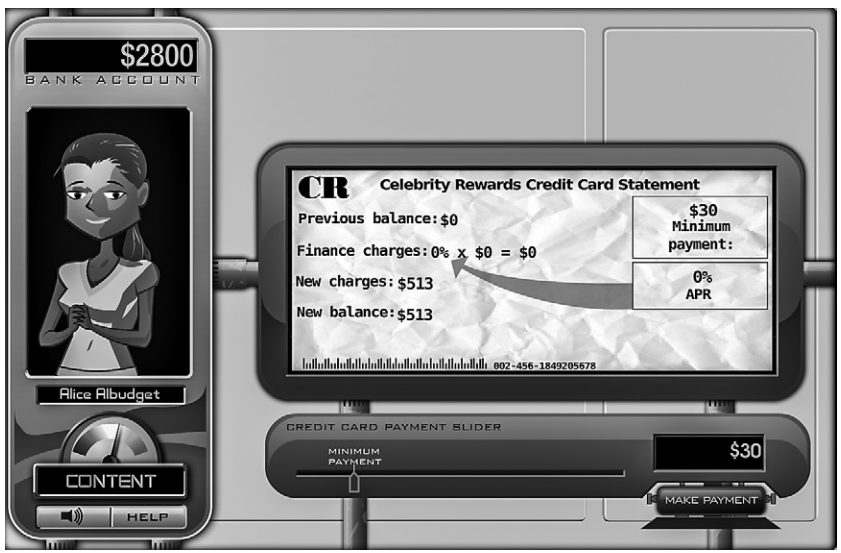

Figure 7.4
The credit card statement at the end of an early round with no debt (© 2017 Commonwealth)

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A Financial Entertainment Empire

Shortly after the launch of *Celebrity Calamity*, Commonwealth engaged in design for additional games. The next two were *Farm Blitz* and *Bite Club*. *Farm Blitz* continued with the theme of managing debt, while *Bite Club* was a game designed for understanding and encouraging retirement savings.

Farm Blitz (figure 7.5) was designed in the style of popular farming games of the time. It also took a more metaphorical approach to debt than *Celebrity Calamity*. The goal of the game was to grow food on your farm, which in turn required paying for seeds on credit. When you took on debt, the debt was expressed in terms of rabbits that were kept on your farm. The more debt you took on, the more rabbits were represented. And just like real rabbits (and real debt), the rabbits multiplied in numbers if you didn't get rid of them.

After acquiring seeds at the beginning of the round, players plant them, and crops spring up. Crops are harvested by moving them around to make rows or columns of three or more of the same type, much like many casual

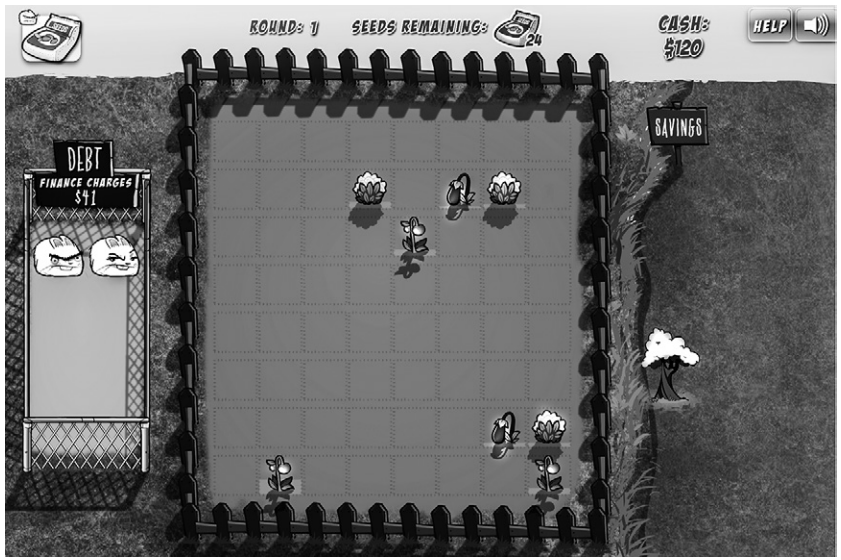

Figure 7.5
The farm plot in *Farm Blitz*, showing the rabbits (debt) on the left, the farm crops in the middle, and the orchard of trees (savings) on the right (© 2017 Commonwealth)

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match games. After harvesting as much as possible, players have the option of paying off some or all of the debt they have accumulated, which gets rid of some of the rabbits, or if players have paid their debt, they can stash some of their money in savings, which is represented as an orchard of trees.

Each round players are given a summary of their debt, savings, and cash on hand (figure 7.6), as well as details on finance charges and interest earned (figure 7.7), followed by prompts urging them to get rid of their debt before it multiplies and to save more trees.

Bite Club took a more direct approach to modeling personal finance, though set in a more fantastical place. In *Bite Club*, you manage a nightclub frequented by various monsters—vampires, Frankenstein monsters, and so forth (figure7.8). The game borrows from task-management games like *Diner Dash* to challenge you to place the customers where they would like to be (e.g., at the bar, or dancing on the dance floor). If you make them wait too long, they will leave, and you will lose them as a customer. Satisfying more customers results in a larger take at the club, so most of the game is spent in this task-management mode.

Figure 7.6
The summary at the end of a *Farm Blitz* round, showing the current debt (in terms of rabbits), cash available (cash), and savings (in terms of trees) (© 2017 Commonwealth)

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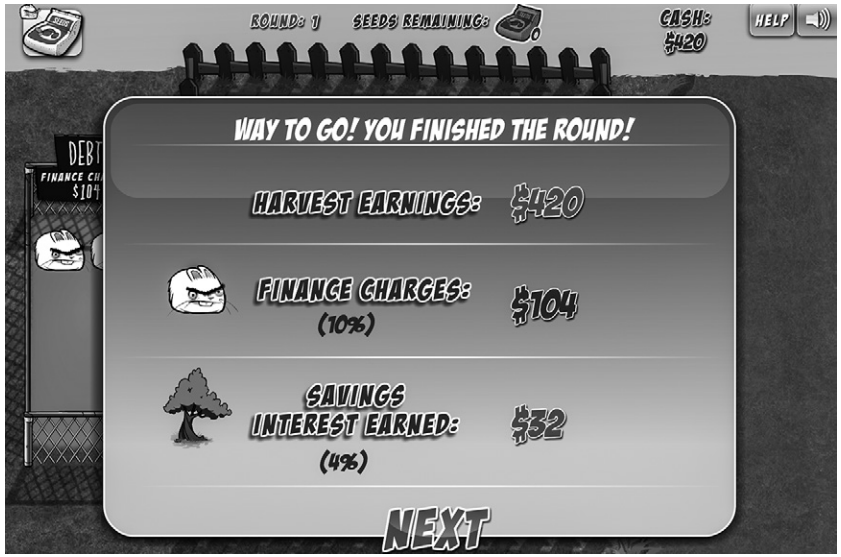

Figure 7.7
End-of-round summary for *Farm Blitz* showing finance charges and interest earned (© 2017 Commonwealth)

Figure 7.8
The primary focus of game play in *Bite Club*, task management, placing the customers where they would like to be before they leave (© 2017 Commonwealth)

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The mechanics are a little more intricate than the other two games, as the demands for the kinds of things that people want are fairly diverse. Some people (err, monsters) are looking for particular conversations with other patrons, some are looking to sit in a particular place, and others want specific drinks or music to dance to. Like most task-management games, *Bite Club* is a bit overwhelming, and a lot of triage is necessary.

Between rounds, you are given a financial update and have to make decisions on where to spend the earnings from each round. This is where the connection to savings happens. You come into the game with student debt that you are encouraged to pay off quickly (figure 7.9). There is credit card debt as well. On the savings side, you have regular savings and retirement savings. Retirement savings even includes an employer match (apparently the *Bite Club* is a good place to work). You need to allocate your cash into the different categories. The one category that is a bit different is retirement savings, which is not only a percentage but also set for several rounds at a time.

Over time, you can also allocate resources to improving the club (adding tables or other amenities, some of which are just nice, others of which

Figure 7.9
The financial management screen in *Bite Club*, showing options to pay off debt and add to savings (© 2017 Commonwealth)

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DON'T LEAVE YOUR MONEY IN CASH!
Pay off DEBT then invest the rest in SAVINGS – it'll be safe there, and it earns COMPOUND INTEREST that can go towards your retirement.
next

Figure 7.10
One of the prompts in *Bite Club*, suggesting paying off debt and getting money into savings, advice that works in the game and in real life (© 2017 Commonwealth)

increase the capacity of the club and consequently increase revenue potential). Like the other games, there are many prompts (figure 7.10) that relate to the game's learning goals. In this case, it is about paying off the debt fast, and then increasing your savings, particularly the retirement savings. To reinforce these goals further, there are periodic challenges to pay off debt or increase savings that result in additional rewards.

Innovating Partners

While Commonwealth was not expressly trying to innovate in game dynamics, they were trying to innovate in partnerships and distribution. This is where they felt the key to their success resided. Nick said,

> Another key part of what we're doing with Financial Entertainment really focuses on the distribution channel and not only providing this information through games, but also through a trusted source. As a result, there were many times when we partnered with employers or educators, or credit unions or banks who licensed our games. At that level we also had several conversations about cocreating games with partners. In terms of distribution, the partnerships were the difference between

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some stranger telling you to play something and someone that you know and trust saying that this can help you. And that's what we've really been able to benefit from as well.

The question was, "How do you get people to play *Celebrity Calamity*?" To convince funders that the games were having an impact, Commonwealth needed to get the games into the hands of people in its target audience and get them to engage in game play. This didn't need to generate revenue, as many for-profit games hope to achieve; it just needed to generate game play. Nick explained,

This was a frequent question multiple stakeholders, including funders, asked us. Even though we had never envisioned just one game to solve it all, we had to start answering that question with just our first game complete. So we created a framework of different venues where we could access the audience that our funders care about—low to moderate income adults, 18 to 35. And then, we pursued strategic partnerships with community colleges, employers, government and nonprofits that could reach our desired audiences.

In some cases, folks came to us. For example, Staples was first introduced to us through a nonprofit in Wisconsin. They liked Celebrity Calamity, but debt and credit management weren't pressing issues at the time for Staples' employees. Since they really liked the idea of delivering content through a game, we were able to work with them on a different game that fit their retirement focus.

In a different example, as you saw in our study, Fort Hood (one of the largest army installations) approached us. They saw Celebrity Calamity and said "Wow! Soldiers play video games, let's do something."

We also partnered with a community college in Indiana, one of the largest in the country. To reach students within their multiple campuses statewide, we conducted several pilot tests through a diverse approach for outreach and marketing. And we saw positive results. In some cases, we engaged users in different types of tournaments and leader boards.

Through testing in different environments, we were able to learn what would work and what wouldn't.

They tried a diversity of partnerships and many of them worked. But not all of them. One of the keys was partners who actually did active marketing, rather than passive distribution. Nick advised, "A lot of people want to take the content and put it on their site, but that doesn't do anything. No one goes to it. Having a partnership where there's true collaboration, where you're thinking together about how to reach the consumer and communicate with them was necessary." Some banks buried the game deep in a consumer portal, while another bank took the effort to create some art

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based on the game and place it on their home page. That bank had tens of thousands of people pass through to play the game, while those who simply buried it in the portal had nearly zero.

Nick explained that those successful partnerships are in fact often rooted in individuals.

> In many of those institutions, there are creative folks who want to try something different, who are given some permission and context in which to do it, and then leverage what the games can offer.
>
> With the community college, the marketing department of the school was the driving force for our games. They sent emails to all students. The number of plays from that email blast was astounding to me! It went to scale immediately.

The breakthrough partnership was with Staples and New York Life. Staples was intrigued by the next game in the Commonwealth lineup, *Bite Club*. That game and its sister game, *Farm Blitz*, were funded by the Social Security Administration through a financial literacy center in which Commonwealth was a partner. Through some network based on the early Commonwealth financial education partnerships, the organization connected with high-level executives at Staples. They were interested in promoting retirement savings and wanted to make specific connections to their 401(k) platform through New York Life.

So this integration was more sophisticated than previous links on portals and home pages. As Nick described it,

> [This version] had Staples branding on it, … because Staples chose to customize the games. That was another piece they leaned into differently from other partners. They chose to add their branding, logos, and links out to the 401(k) platform, so people can go straight from game to action playing. They chose not to use email marketing, so, we used paper-based marketing with a URL. And people still found their way and played.

Even though most of the distribution was offline, in break rooms with posters and little strips of papers, the reach was quite successful. In some places Commonwealth saw 80–100 percent action rates, where nearly all employees were logging into the games, playing, and taking action. This is in places where "the stores were committed." This storewide commitment help contribute to the creation of communities of practice in the break room. People who worked in the store could converse and share stories about their game play.

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This is a part of the Game that connected game play with the players' lives. These connections were not distant and intangible, but rather proximate and very discrete. There were specific actions that they could take that seemed meaningful in the context of the game and in their own lives. Nick described what happened during the second push for the game, which came around Halloween:

> They had magnets and various other marketing materials common in other employee wellness initiatives but this time with vampires. And then two days before the launch, they pulled the plug because of an unexpected project. The games went viral anyway on their own because word had gotten out. There was all this demand that they were surprised to see. So their team wanted to figure out how to build this in the right way and do outreach. And then, that got them excited to customize the games further and build in the action-taking components.
>
> And so we customized the games to have links in them at key moments, when we think your stress levels might be at the lowest, just basically guessing, here's a hot link out to the New York Life platform. Go do something. Enroll in your 401(k), increase your contribution, check out the various resources, do something.

Success Is Learning from Failure

Part of creating successful partnerships is learning from unsuccessful efforts and either walking away from them or turning them around into something successful. As Nick Maynard said, "The failures are more important than the successes because it helps navigate us away from what may or may not work."

And along with Commonwealth's many successes, it also had a lot of learning opportunities. The failures, or learning opportunities, are useful to think of categorically. It isn't that the partners are necessarily bad, misaligned, or naive, but there are some structural underpinnings to these partnerships that lead to problems.

One category is *partnerships that position the game as an opportunity (or obstacle) within a very directed experience*. Nick described one example of a portal that was being built for low-income individuals to find information. The game was placed among the other resources on the site. But no one clicked through. "They didn't use it because … if you're going to that site, you're looking for something. You're not going to stop and play a video game. You're trying to solve a financial problem and you need resources for that."

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Learning from that experience, Nick explained why Commonwealth walked away from another partnership that was designed to set up the equivalent in-person approach.

> We had a great relationship with a large financial institution. And they suggested distributing our games through their branches. Because of our research we in fact turned down this offer. While games in a branch sounded great in theory, the model wouldn't work. Customers in branches want to engage with staff about their financials or branch business, and that's exactly what they should do. They could use the games within an advertising campaign, for example, if they felt that would be attractive to customers, but our games wouldn't benefit a consumer's branch experience.

You also *need a receptive audience*. If people aren't open to the ideas that you are trying to deliver, then it is definitely a steep climb. Commonwealth saw this in the domain of student debt. A large state university with one of the highest student debt rates in the country called the organization. The university wanted to use the Commonwealth games to help students address the issue. So Commonwealth went out and tested event marketing. The market testers had people dressed as characters from the game, they had kiosks where people could play, and they spread information, but there was no uptake. Ultimately, they decided that trying to reach really busy college students about a topic that they really didn't want to face at that point was a recipe for failure.

Some of the failures came from what has now become obvious—that communities are required to sustain learning, and *the lack of community* often bodes poorly for spread. Commonwealth has had success working in military bases. Often these are long-term communities of people who know each other well. In other cases, the communities are much more transient and ephemeral. In cases where the community was long term, word of mouth made the games quickly go viral. In cases where the community was weak and short term, that word of mouth never helped the games spread.

But as much as you can learn from successes and failures, there is still something unpredictable about where the game will spread and where it won't. At one point, Commonwealth had a partnership with the state of Massachusetts, with two avenues of distribution—state employees, and community colleges. State employees simply got a link on their pay stubs to the game site. For the community colleges, student ambassadors were

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selected to try to spread information around campus. The latter certainly required more effort and was more deeply embedded in existing communities. Despite that, the pay stub effort worked really well, and state employees played the game quite a lot (sometimes at work, which was not prohibited, as it was at Staples), while the school ambassadors had little success in the schools. Different populations and different opportunities, but still hard to predict all the factors leading to success and failure.

Schools

One of the places Commonwealth has had a lot of success, which it didn't predict initially, is in middle and high schools. The games were not designed for school usage, but Commonwealth found that there was a "halo effect" that moved the games from the adult market into schools. At first it was just word of mouth getting passed around, but once Commonwealth was able to get a glimpse of who was using the games and why, representatives started to go to conferences where those teachers were to attract more. One such conference was that of the Council for Economic Educators. It turns out that many of the classes that teach economics also try to mix in some personal finance. Nick said,

> One of the things that we've heard over and over again is, it's hard to teach personal finance when you're not a personal finance teacher. Because you yourself may not be a pillar of financial health. And so the responsibility of imparting wisdom that you may or may not be comfortable with yourself can be hard. But teaching kids to play a game is not hard.
>
> I think there's a comfort level. The bedrock of our games is breaking down some of the anxiety around introducing financial concepts. And that worked in terms of talking to a group of teachers about playing this game with their students. They don't have to be experts. It's about introducing concepts and understanding how money grows or money goes away, and how that works at a level that they feel comfortable with.

That initial success in schools led to grants specifically targeting schools. Banks were eager to offer local partnerships that targeted the games at those in need. Capital One partnered around *Farm Blitz*, one of the games that already had some teacher activity. Of course, fitting the games into regimented class periods and lessons is a challenge, particularly when they weren't designed with those constraints in mind. But interest and adoption were high. It met a lot of other classroom requirements—opportunities for

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individual and group play, connections through reflection, and a low barrier to entry.

Another partnership was with Zion's Bank in Utah and Idaho. That partnership targeted 250 schools across those two states. The bank had a financial literacy executive who was looking for new outreach opportunities. Through that partnership, Commonwealth was able to tap into existing activities and outreach, adding a game to existing infrastructure already set up to reach students. And it was a big win for the outreach to include a game compared to the pamphlets students were normally left with.

Over time the games have reached at least one district in all fifty states. And the adoption keeps going. There are schools that preload some of the games on their iPads. And schools come back year after to year to use the games again.

Research Op

Commonwealth has used data to show that what they are doing is effective, and that has opened up further opportunities. It has also engaged in a lot of research, though one of the most interesting studies was more naturalistic.

In the classroom, teachers often think of games as a tool to use to reinforce knowledge that the students have been taught in another way. But we think of games as an experience that gets students thinking and ready to learn from other media. A game prepares the student for future learning (Bransford & Schwartz, 1999).

Commonwealth was doing some outreach in afterschool programs through one of its bank partners. Commonwealth team members had two activities planned for the students, a computer lab for playing *Celebrity Calamity* and a related financial literacy lecture from a bank representative. It turned out that they didn't have enough room in the computer lab for the entire group, so they had to split the group up into two. One group had the lecture first and then played the game, while the other group played the game first and then got the lecture. Nick described the results of this program.

In both cases when they played the game, pre- and post-test, scores went up. In the scenario with the lecture first, you have a volunteer from a bank doing the normal

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outreach. This group of kids didn't pay attention, weren't engaged, and didn't ask any questions. The volunteer didn't have a good experience, nor did the students.

The [other] group came out of the [game] sessions, and went into the lecture, and was engaged and asking lots of questions. Their brains were turned on. So, it was better for everybody. They were asking questions relevant to the game. They wanted to know more about what the characters were doing, and why they were doing it. And then the group that came in for the game [after the lecture] asked why they didn't get this first? It was very interesting because we didn't set it up that way—it was all based on numbers. But it became a natural experiment.

The scenario in which the students got the game first and then the lecture was a lot like the design of the game deployment in Staples and other places of business. They got the game first, which primed them for the next activity. For the students, that activity was about engaging in conversation about personal finance. For the Staples employees, it was learning about 401(k) options.

This action is what all the funders are concerned with, and it is what perpetuates the collaborations at Commonwealth. Nick said,

If you were to create a system where someone plays a game, and then takes steps to save money, or read about information related to an account or features. … That's a financial action that can be measured. People care about that impact. People care that—it's not just that 25,000 people played this game [but] 25,000 people played the game, finished the game, and also saved $10 today because they played the game. And for no other reason, would they have saved the $10, right? So that's what we're interested in.

Conclusions

As outsiders to game design, Commonwealth has some big takeaways that have driven its work and collaborations.

The first piece of advice is that there is a "difference between really being a *partner* in a project versus being like someone that we hire as a vendor." For much of the work that Commonwealth does, it could simply hire contractors. And in some cases, those contracts could even reduce short-term costs, but partnerships are enduring and lead to future work. Thus Commonwealth invests in partnerships.

Second, team members work with people who are going to *challenge their assumptions* and work toward the best outcome. It isn't about finding partners that agree with everything they say and take direction. It is about

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different partners bringing their strengths to bear on the project, and working toward a shared goal.

If some of this sounds strange, Commonwealth also notes that making a game for change (or a game at all) is "different than making software." It is an iterative and creative process with outcomes that are clear, but the exact pathways to those outcomes need to be created and dreamed up.

And finally, the best advice that they could offer: "Play as many games as possible."

Note

1. N. Maynard, personal communication, March 18, 2016. All quotations from Nick Maynard and Commonwealth in this chapter are from this personal communication.

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8 Measuring Resonant Success

As both creators and researchers of educational games, we are often asked, "Do games work?" This is, of course, an unanswerable question. Similarly, we can't answer (and haven't tried to answer) the question, "Do books work?" It depends on the definition of "work." What are the desired outcomes and how are those being measured? And do those measurements matter? We must also consider which books, which students, which learning goals, which teachers, and which context we are asking the question about. There are too many variables to give any single answer to this question.

There is a rush to draw parallels between education research and medical research. The rationale is that medicine has defined a set of standards and protocols for determining whether medicines "work" or not. The randomized controlled trials of medicine are seen as a gold standard to many and can tell us whether something "works." There are many problems with this "health care envy" (Squire, 2011, p. 232). And those in the medical field know all too well the problems with this gold standard. It is hugely expensive and rife with contested, biased, and manipulated results (Ioannidis, 2005), as well as many cases in which the results are highly dependent on the context of the study (Open Science Collaboration, 2015). This isn't to say that randomized controlled trials are always a waste of resources, but that this methodology should be looked on with great scrutiny.

Instead we should embrace a diverse set of research methods, data sources, and analytical techniques that match the intervention, context, and outcomes. Our process involves asking what would make this particular game *resonate*? As we describe in the previous chapters, each of the games we have profiled embodies different principles, was deployed in different contexts, and had different desired outcomes. So how would we know if that game is resonating with the audience in the chosen context?

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The first step is to *align* the measurements and data collection with the game goals. This may seem obvious, but often data are used because they are convenient rather than well aligned. School exams, surveys, and in-game data have their place, and are often convenient, but they don't always provide the best alignment with game goals. For example, *Vanished* was designed to help increase student interest in science and proficiency with using scientific data in argumentation. Even if we could have used school exams, they wouldn't have been aligned with these goals. We needed to use more appropriate data to measure these outcomes.

Games scholar James Paul Gee has often said, "Nobody gives a Halo player a test afterwards to find out what they learned. The evidence of their learning comes from their success in the game itself." In other words, being great at *Halo* is evidence of *Halo* performance. But many times, we as teachers and researchers are interested not only in how the students did on a particular task, but also in how well they transfer some of that skill and understanding to another context. We might want to know how well they transfer their in-game genetics skills to solving genetics problems on paper, or how well they transfer their skills in forming hypotheses to laboratory projects.

Such transfer is in many ways the holy grail of teaching and learning, as well as a hugely challenging problem (Bransford & Schwartz, 1999). It turns out in general, people are not good at applying something that they learn in one context (e.g., a mathematical concept like ratios and proportions set in a context of pizzas) and applying that in an entirely different context (e.g., the same mathematical concept of ratios and proportions applied in a context of weights of objects). We need to be taught how to bring the ideas from that one context into the new one.

Gee (2003) has also argued that games are really good at promoting such transfer. They do this by constantly asking players to transfer their learning from one context within the game to another context within the game. For example, players might need to stack boxes at one point in the game to climb out a window. Later in the game, they may need to stack barrels to reach a seemingly unreachable object in that room, or to build a bridge of boxes to cross a river. The nature of getting better at the game is learning these game-specific skills and applying them again and again, often in novel ways. Thus, it may seem that doing well in *Halo* is actually doing well in a series of increasingly complex and diverse versions of a task, setting

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up players to at least transfer those skills to another, similar kind of game. Given how bad people seem to be at transfer, this kind of scaffolding and learning to transfer is a significant accomplishment for the medium.

The question is what do we want our players to transfer their understanding to? What could we measure and use as evidence that someone has learned something that may have meaning beyond the game itself?

It is most useful to think of these measures and outcomes in parallel with the design of the game itself. While some measures can be put into place post hoc, there are two big reasons to think about these measurements earlier in the design process. First, the game activity might change to help collect the necessary data. For example, in *Radix*, since we wanted data used as evidence, we needed to make sure there were opportunities within the game to use data as evidence. Second, the data that the game collects might be changed. So perhaps the desired activity (e.g., using data as evidence) is already a part of the game, but those data need to be kept in a useful and easy-to-parse way to be analyzed later. This is one of the big challenges of learning analytics—collecting the useful data and just the useful data.

In general we define five principles (the five A's) for data collection and measurement to provide evidence that a particular game is achieving the stated goals (figure 8.1). These principles are artifacts, affect, audience, assessments, and analytics.

- **Artifacts**—The products that players produce within a game or a game context that can be captured. These are often complex products, like written dialogue, or multimedia (photos, video).
- **Affect**—The feelings players and their teachers/mentors have about the game and the game experience. Do the players like the game and come back to it?
- **Audience**—Who the game is reaching. Does the game reach its intended audience in terms of age, diversity, skill, and numbers?
- **Assessments**—Instruments provided to players (often outside the game) that measure player knowledge and understanding. These can range from multiple-choice tests to concept maps or choice-based tasks, often provided in a pre- and post-style (before and after the game).
- **Analytics**—In-game data that can be collected about player performance and usage. These data can be mined and analyzed to get insights into player patterns, learning, and engagement.

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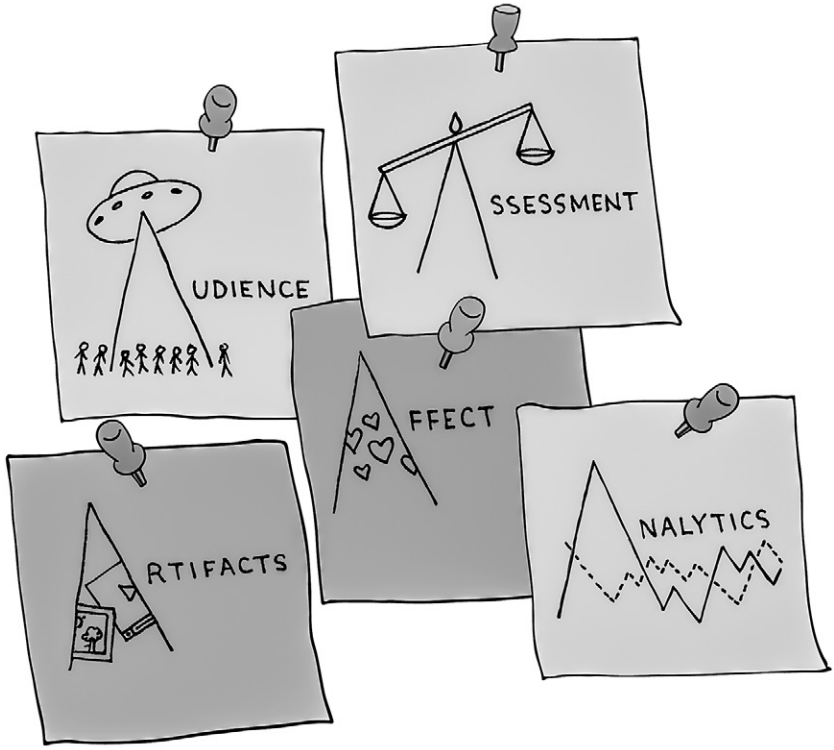

Figure 8.1
Five principles for data collection and measurement

All five of these principles then need to be considered in c*ontext*. Who is using the game? How are they using the game? Where are they using the game? Each of these variables is important for understanding the data provided by the five A's.

Let's take a deeper look at each of these, where they have been employed in our games, and where they find the most utility.

Artifacts

Artifacts are products that players produce in conjunction with game play. These can sometimes be produced in the game itself. In other cases, they are produced in activity around the game. Artifacts help to make thinking visible—to enable researchers and teachers to see what and how students are thinking about their activities.

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Vanished involved a series of complex tasks performed by the players. These tasks often involved the actions of dozens, hundreds, or thousands of other players. Creating evidence from these complex tasks similarly required complex multidimensional data. Much of the action of the game took place in the forums. This forum activity provides ideal data about student activity.

Early in *Vanished*, the players were given a task to collect temperatures across the United States. This task led to a conversation about why they needed to collect the temperatures. Many of the students simply posted the temperature at their location on that day, sometimes without even noting anything about the location. Eventually the discussion (figure 8.2) turned to why they were collecting the temperatures. Most of the students seemed to respond with various forms of "because we have been asked to." One student (150103) provided some explanation of why they might be asked to do this particular task. "A lot can be determined from weather patterns. Did you know the fall of Rome occurred in a time of drought? We know this from the rings of trees. They are thicker when there is a lot of rain, and thinner when there is not much rain." The conversation after that, however, fell back to something more along the lines of "because they asked us."

Later in the *Vanished* adventure, the students discussed the role of a potential reversal in the magnetic fields of the Earth. This conversation showed a much greater depth of evidence citation (figure 8.3). For example, one student (Amgine) offered up an "article that talks about the Earth's magnetic poles and the possible consequences of them switching." That was linked to the migratory patterns of animals, and another student provided a citation from the National Parks Service that talked about the reasons animals migrate. This conversation (partially prompted by moderators) contained a lot more evidence—data from the game and from outside sources.

Another task involved collecting pictures and Latin names of local flora and fauna (figure 8.4). This task could not be assessed individually. It could only be looked at across the entire group. Was there representative data from across the country? Did posting of some species spark the posting of other species? How did the discussion in the forums support the progression of species posting?

Analyzing this kind of conversation is challenging, but clearly in this case, only these kinds of complex data could give us insights into the

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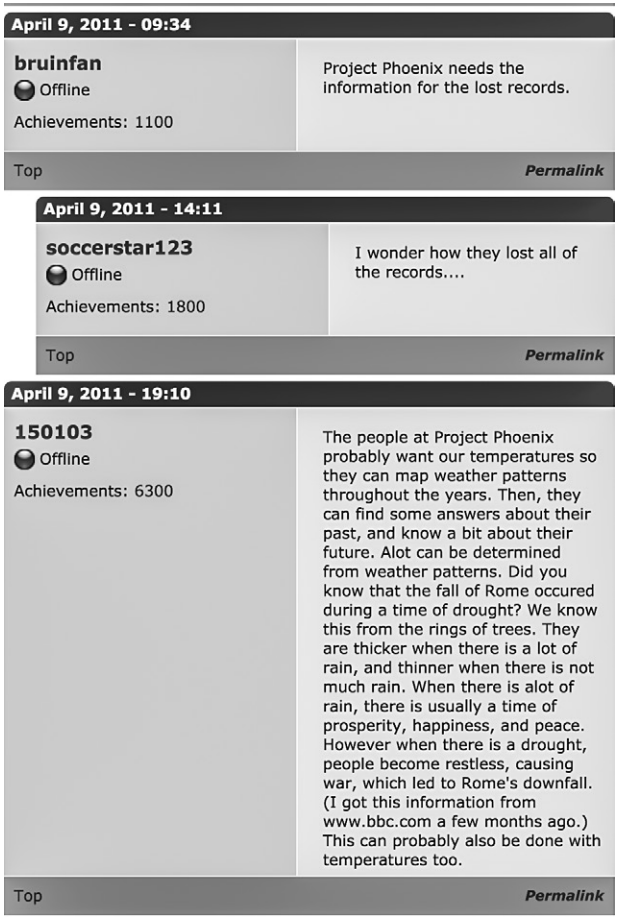
April 9, 2011 - 09:34
bruinfan
Offline
Achievements: 1100
Project Phoenix needs the information for the lost records.
Top
Permalink
April 9, 2011 - 14:11
soccerstar123
Offline
Achievements: 1800
I wonder how they lost all of the records....
Top
Permalink
April 9, 2011 - 19:10
150103
Offline
Achievements: 6300
The people at Project Phoenix probably want our temperatures so they can map weather patterns throughout the years. Then, they can find some answers about their past, and know a bit about their future. Alot can be determined from weather patterns. Did you know that the fall of Rome occured during a time of drought? We know this from the rings of trees. They are thicker when there is a lot of rain, and thinner when there is not much rain. When there is alot of rain, there is usually a time of prosperity, happiness, and peace. However when there is a drought, people become restless, causing war, which led to Rome's downfall. (I got this information from www.bbc.com a few months ago.) This can probably also be done with temperatures too.
Top
Permalink

Figure 8.2
Discussion of temperature patterns in the *Vanished* forums

nature of argumentation from the students. These in-game artifacts were invaluable not only for game play but for analysis of the game's success in promoting and building student use of evidence.

Artifacts can also be created outside the game. Teachers using *Radix* often had students prepare lab reports, blogs, or other forms of out-of-game data capture of their experiences. For many teachers, this provided an easier and more comfortable way of assessing the activity that the students performed in the game.

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April 25, 2011 - 18:59
Flying_Narwhal
Offline
Achievements: 7600
That could explain a lot! Great job! So many species could have gone extinct because they rely on the magnetic poles to guide them. The article also mentioned that the magnetic field surrounding earth could disappear for a century or more. The year we received was 2300 something, right? So maybe the weather was very erratic and that could explain why Jasper's time period seems to be in a cooling period.
Top
Permalink
April 25, 2011 - 20:46
demyx4ever
Offline
Achievements: 7440
so if the magnetic poles switch, migratory animals could get confused right? and if they don't know where they're going, they could possibly "migrate" to the wrong place and end up dying because it's too cold. but i have one question, even though animals could get confused with the switching of the poles, don't some animals have this sense where they can tell which direction is which even though everything's all crazy?
Top
Permalink
April 25, 2011 - 20:50
yeti
★ Moderator ★
Offline
Well, how do animals sense where to migrate?
Top
Permalink
April 25, 2011 - 20:56
test123321
Offline
Achievements: 9400
According to the Park Service "How do animals know when to migrate? That depends on the type of migration. For many types of migration it is the change of seasons that spurs animals on. As summer becomes fall, days become shorter and that can trigger animals to prepare for migration."
"Other migrations are initiated by seasonal conditions. Food availability can be a motivator for some longitudinal and altitudinal migrators."
"In some species, migration happens when there are just too many animals too close together. "
So sometimes because of weather, sometimes because of social cues, and sometimes because food runs out, and the animals move on.
Top
Permalink

Figure 8.3
Discussion of the possible change in the magnetic poles in *Vanished*, using citations and evidence, both important in the discussion

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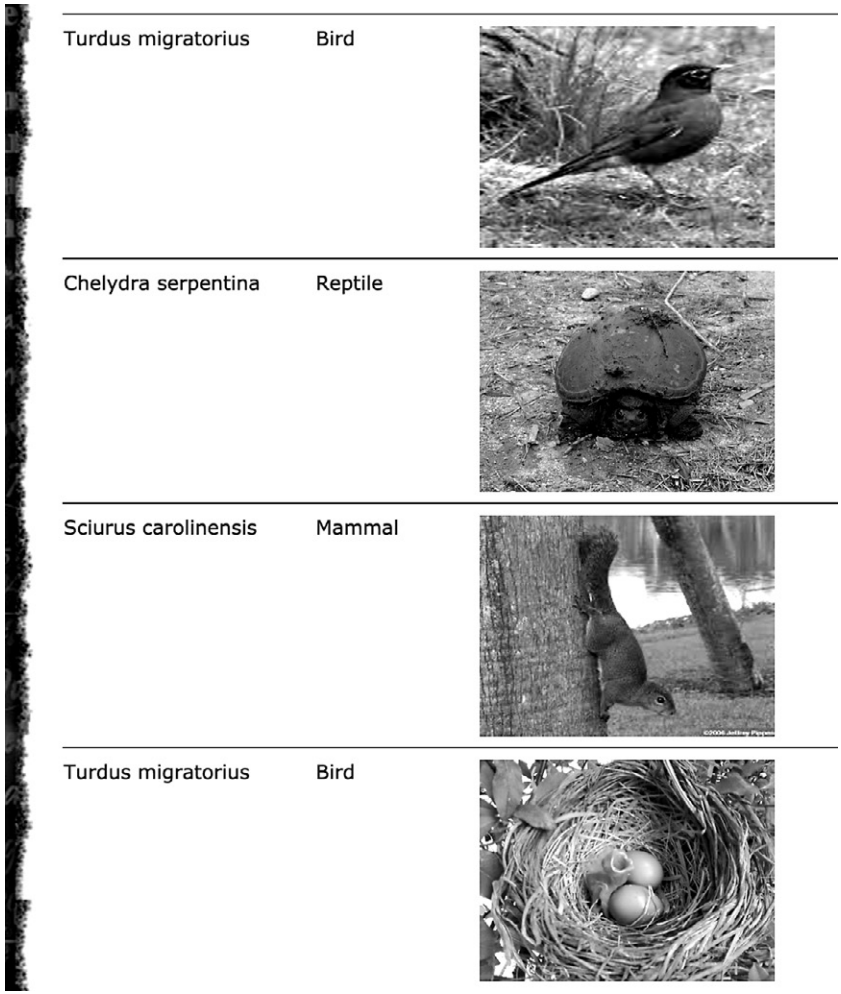

Figure 8.4
Some of the information about fauna collected by the players of *Vanished*

One example from earlier in our work in the Education Arcade that illustrates this is from the game *Revolution* (Francis, 2011). This was a game in which players role-played as ordinary people in Colonial Williamsburg on the eve of the American Revolution. The players took on the roles of common folk like blacksmiths, barrel makers, and slaves. Their task was either to provoke the revolution or stop it from happening. The goal of the game was to promote students' thinking from the perspective of

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the average people at the time, who were such an important part of the revolution.

As part of the research, players in many classes were asked to make screencasts (video screen captures from the game that they narrated) to document their experiences. This provided not only documentation of what they had done in the game, but rationales explaining why they had done these things. It was ultimately a way to capture a lot of data about player activity and thinking. It would have been extremely challenging to collect these kinds of data solely from in-game data (even if we had had the analytics that we have now). These video diaries captured a much more multidimensional set of data. They had the additional advantage of providing utility to teachers. Educators often struggle with how to "grade" the game play, but it is a more familiar experience to grade student projects, such as this. Most importantly, it also provided a richer experience for the student players themselves. They developed deeper insights into their characters and connected with the narrative in ways that they had not as they simply played the game. This represents the ideal for data collection—the collection itself not only doesn't detract from the experience, but actually enhances it.

Affect

Many conversations about the nature of games turn to the concept of "fun," though most scholars don't include fun in their definitions of games. Instead they focus on the structures of games, such as rules, systems, and outcomes (e.g., Salen and Zimmerman, 2004; Juul, 2003). But the result of these structures—the rules, systems, and outcomes—is intended to engage the player. For many game designers, including ourselves, "fun" may be the wrong word because of its associations. "Fun" conjures up notions of wild enthusiasm and continuous heightened engagement. While some games may be designed to elicit that response, many others are designed to elicit other kinds of engagement. The structures of the games challenge players so that they are deeply engaged.

We often recall Seymour Papert's (1998) previously noted concept of "hard fun." Papert was working with kids using his Logo programming language. He found that the students he was working with often wrestled with challenging problems. In the moment, the students would likely

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describe that feeling not as being "fun" but rather as being "challenged" or even "frustrated." Eventually they would overcome that challenge, either through some insight, help from a friend or teacher, or even sometimes trial and error. That feeling of solving the challenging problem was quite satisfying. While Papert called this "hard fun," a good argument could be made for thinking of this simply as "fun."

A similar feeling is obtained when playing many games. Games that are too easy are not engaging. Players who pick up games that provide no challenge often put those games down very quickly. Instead, games that continuously provide players with challenges that are just a little too difficult elicit the most engagement. These games may be thought of as keeping players in their zone of proximal development (Vygotsky, 1978), the space between the things that they can't do at all, and the things that they can do easily by themselves. This is the space where learners can do things with help, and it is the space where the most effective learning happens. Good games keep players in that space, where they are engaged and learning.

The concept of "flow" (Csikszentmihalyi, 1975, p. 36), "the holistic sensation that people feel when they act with total involvement," is also associated with some types of games, particularly long-form games. It is a state reached when the player's skill and the game difficulty are well matched. If you've played a good long-form game, you certainly know the state. You are immersed in a task within the game, trying to solve a problem, and before you know it, hours have passed. This is related to and sometimes confused with a notion of immersion, though immersion (Jennett et al., 2008) may be induced by many design elements of a game beyond challenge, including narrative and aesthetics. Regardless, there seems to be a connection between these emotional states and learning that is useful to capture (see Hamari et al., 2016, for a discussion of this research).

While "hard fun" and "flow" can be distinguished from the naive notion of "fun" in a frivolous sense, they are emotional states that have the potential to be productive and keep a player engaged in the game. These are the states that we try to create in *resonant games*. We could even say that one way the resonance of games is apparent is in how it puts players in this state of being continually challenged, learning and overcoming those challenges. So one way we want to know if the game is succeeding is through evidence of this kind of engagement.

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There are many new ways of trying to measure engagement, including galvanic skin response (sensors that are attached to the skin that measure changes in electrical conductivity that can be correlated with changes in mental state), eye trackers/sensors (cameras that can measure where someone is looking or the dilation of their pupils, or other kinds of cameras and sensors that correlate expressions with emotions). While these may have a place, we don't use any of them, for several reasons, including that they aren't particularly reliable at this time (at least for measuring something like flow, though some researchers have made progress on this, e.g., Nacke & Lindley, 2010). They are also expensive and challenging to scale. Perhaps most importantly, they primarily measure proximate measurements of engagement. What we really want to know is what the player thinks and feels.

The most common way of measuring engagement is through surveys. These are highly scalable but often not particularly reliable either. You ask players a series of questions about what they thought about the game, how they felt, whether they'd be likely to play again, and so on. These are often measured with a Likert scale (e.g., a scale of 1 to 5, with 1 being "would be highly unlikely to play the game again" to 5 being "highly likely to play the game again"). We often use these as one measure because they are easy to obtain and they can be helpful, particularly when comparing games or parts of games that we have created and used with a particular audience. The problem is that the responses are usually between 3 and 4. While we might see statistically significant differences between groups, games, and contexts, these differences are often small in magnitude, and one has to question whether a difference of 0.1 on this scale is practically significant. Still these kinds of data can be a useful first pass on engagement when comparing similar products. For example, in UbiqBio, where we deployed a series of games in a similar format to the same group of students, we might be able to learn something about student preferences comparing their ratings across the games.

But there are other ways of measuring affect. Many researchers are now looking for direct biometric measurements of affect. As mentioned above, for some time galvanic skin response has been one such measure. As someone becomes excited, their conductivity changes, and sensors on the skin can measure such response. More recently researchers are using pupil dilation as detected by webcams to measure similar excitement. We have not

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employed any of these methods for the reasons we give above as well as another important reason: they are all intrusive. Such intrusion is not only off-putting for many players, but it may actually change their perception of the experience itself, which defeats the purpose of these measures in the first place.

In many ways, players' immediate response to the game is less important than their memory of the game anyway. We care about what they think they felt about the game—what they might tell their friends, or what might incite them to go back to the game again. As such, we look at measures like how much time they played the game (either measured through logs that the players keep or more recently through analytics), or how much they played the game beyond what they were required to do. We can look at how long they played each session for, or whether they did more tasks in the game than required. All of these give us insights into what matters, whether the game is appealing enough to play on its own. We can also look at the ultimate learning outcomes that we hope emotional engagement will bring

Direct observations are another method that we can employ, although this is limited for games that are played primarily outside school. For those played in school, we can directly observe the student experience. We can record conversations between students as they talk about the game, or note where conversation seems to stray far from the task at hand. We can watch for students who play until minutes after the bell has rung, or those who turn off the computer in advance and anticipate the bell. These provide powerful indicators of whether students do indeed like the game.

Interviews can also work well. We can interview students to find out not only whether they enjoyed the game, but what in particular they enjoyed or felt like could use improvement. This not only helps us determine whether the game is good or bad, but more importantly helps us iterate on our designs and form design principles that we can carry forward to future games. These are some of the most important insights that we can receive. This feedback that allows us to change designs or synthesize principles across projects are the ones that can truly bring about a difference. In addition to interviewing students about their opinions of the game, we also interview them about the content in the game—what they are doing, what they think it's about, why they are choosing to pay attention to or ignore particular elements. Through this we can learn a lot about how they

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are problem solving in the game, whether they're enthusiastic about it or see it as just another assignment, and what elements they associate with those opinions.

The parallels in the commercial gaming world suggest that our methods are on the right track. What players look at in determining whether they will like a game are the reviews—both professional and from their peers. They look at the number of stars or ratings on a scale of one to ten or to one hundred that the game has received from sites they trust. They read the reviews that describe what players like or dislike. This combination of simple Likert scale results and qualitative data best describe the likability of a game.

Audience

The most obvious aspect of audience that we might be concerned about is its total size. And in many cases, this does matter. It matters that we can say that 33 million pets have been saved by players in *Lure of the Labyrinth*. Or that we have had nearly twenty-five thousand players in *Radix*. They show that we have been able to get to scale. But focusing too much on scale can be detrimental. It may be more important to reach a particular audience than a broad one.

Scale doesn't always matter. Sometimes dozens or hundreds of participants is entirely adequate to get the intended research results. This was the case with UbiqBio. We weren't doing research that required thousands of users, and the games themselves were made primarily for research (though we do try to maintain them for teachers). If the intended outcome is research, not product, then those numbers will suffice. What matters in those cases is which particular students were involved. If the claim that we want to make is that our game works well for low-achieving students, or students who haven't already identified as being interested in a topic, then we need to make sure that the audience that we have selected actually reflects those aspects. So we always need to get data about who the audience is, so that generalizations about results can be made in that context.

Often we are interested in differences between particular audiences. Is a game more appealing to males than females? Are teachers in low-resource schools as likely to pick up the game as those in high-resource schools? Are

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people who identify themselves as gamers as likely to stick with the game as those who do not identify themselves in that way? Collecting and comparing this information can be critical. We are always interested in these differences. Sometimes we may be targeting a particular audience and we want to make sure that we got it. *Bite Club* and *Farm Blitz* targeted young adults. If the game wound up attracting a substantially older audience (even if it was large in scale), it might be considered unsuccessful. Other games might target particular kinds of learners, those with a particular science misconception, or perhaps students with a learning challenge. *Vanished* was targeting middle school students outside school. If the audience primarily came from in school, then we would not only interpret results differently, but interpret the success differently as well given that it was designed to be a model that could attract students to science outside the classroom.

But scale can matter for several reasons. Sometimes scale matters because the funder wants to make sure it is funding not a niche research project, but something that ultimately reaches a mass audience. A large scale means that their investment is affecting more people, which makes a lot of sense. Other times scale matters because the kinds of research questions that we are asking demand a large audience. Some of the analytics research that we discuss below, while not always strictly "big data," is often big enough where the patterns can only be detected with enough data. Finally, some projects have a combined goal of research and product development. In the case of *Radix*, for example, one goal was to create a sustainable product, one that we could keep alive beyond the end of research funding. While we are still working on that goal, showing an audience that is large enough to potentially sustain a product is a critical first step. In many of these cases, audience alone is a necessary but not sufficient metric. We would also need to view it in the context of how those players were engaging with the game.

Scale isn't a simple function of the quality of the game. It is also a function of the nature of the game. (Is it about a narrow academic topic, or something broadly applicable? Think about the UbiqBio games that target primarily academic topics versus *Farm Blitz* and *Bite Club*, which are about financial literacy). Marketing, however, may be the largest contributor to scale. Unfortunately, marketing is something that isn't budgeted into most research projects. Many funders feel that marketing is not what research

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projects should be doing. But as more projects seek to create products or work in the realm of big data, we have a serious need to make sure marketing plays a role in the project.

Assessments

Assessments, whether they be customized or standardized, often play a significant role in determining the success of any of our academically oriented games. Usually people are concerned with what students can do beyond the game, not just what they can do inside the game. We (and many others) have argued that the game itself may be a better assessment of what students can do than a traditional written assessment. After all, the game can dynamically adapt to student performance, present them with multistep complex tasks, and set tasks in a more authentic context. Games that are designed using a form of evidence-centered design (Mislevy et al., 2003) try to do just that. In this approach, the designers need to start with a model of what they want the student to know (student model), work toward what evidence they could actually see showing that a student knows those things (evidence model), design a task that could elicit that evidence (task model), and put together a system (a three-part process) that would enable the designers to implement these models. Balanced design (Groff et al., 2015) is a simplification of this idea that was created to make the ideas even more accessible to game developers. This is simplified to a content model, which includes what designers want students to know, the evidence model of how students would demonstrate knowledge of that content, and the task model of what the students would engage in. Evidence-centered design is for the design of all assessments, not just games, and illustrates good practices for assessment in general. As more game designers follow these processes, we may come to the day when well-designed games serve as the assessment themselves, but this is not the case today.

The story of *Radix* demonstrates this tension that still exists between data from the game and traditional assessment. When *Radix* was proposed, it did not include external assessments. We wanted to diagnose student understanding through their ability to complete the in-game tasks. Later, after the project began, we were asked to provide validation via external assessments. But what did this mean? Their performance on the state exam? On a test we made up?

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The challenge with standardized assessments in cases like this is that they are very coarse-grained measures. They test a wide range of topics, most of them fairly superficially through short-answer and multiple-choice questions. In a domain like science, they also still primarily test factual knowledge, not more complex conceptual understanding, which is what we target in our games. So even if we do a lot better at teaching the things that we want students to learn, we won't see significant changes on the current battery of standardized tests (although there is hope that they are getting better, as tests designed around conceptual knowledge start to emerge).

The alternative is a custom test. While we could certainly write a test with relevant questions, it may not be particularly meaningful. Designing tests that are valid—where items are shown to be related to constructs, student understanding by item is correlated to other measures of understanding, the test is unbiased, and so forth—is difficult and expensive. A good assessment of the concepts we were targeting with *Radix* could have cost nearly the same as the game itself.

Instead we went with a hybrid approach (an approach we've used in other projects, including UbiqBio). We compiled relevant items from already validated standardized tests, but selected items that were only on the topics that we were targeting in the games. This provided enough specificity to allow us to try to measure the constructs of interests, without incurring the costs and complexity of a completely new assessment. It also provided an important validation for the teachers who were using the game. As it turned out, in most of the topic areas, students did improve by playing the game as measured by these assessments. But this is not true in all the topics, which once again demonstrates that it isn't about whether a game works or not but where, when, and why it works that matters.

Ultimately the assessments that we use must connect back to the policies and practices of the context in which they are being used. Right now in the United States, assessments that are economically efficient and reliable are still the norm. The resulting instruments are fairly static and knowledge oriented. Shifting to more dynamic and process-oriented assessments, including game-based assessments, requires an investment in research and infrastructure. There have been problems of approaching this issue at scale, because of the fragmented nature of state-based high-stakes assessments. The demand for assessments that align with new standards,

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frameworks, and most importantly desired twenty-first-century industry competencies, does apply some pressure that could result in real change. Game-based assessments stand to both benefit from and contribute to such a change.

Analytics

Big data is revolutionizing many fields, from medicine to social science to computation. In a recent report on big data and learning Dede (2015, p. 2) defines big data through the four Vs:

> The four "Vs" often used to describe what makes data big are (1) the size of data (volume); (2) the rate at which data is produced and analyzed (velocity); (3) its range of sources, formats, and representations (variety); and (4) widely differing qualities of data sources, with significant differences in the coverage, accuracy, and timeliness of data (veracity).

As more learning activities take place online, the significance of big data, and learning analytics (the analysis of big data as applied to learning) is rapidly increasing.

Games have long been looked to as a place for interesting big data. Game companies themselves have used this kind of information to improve game play. With reference to Gee's earlier comment about "no one testing Halo," in fact, Microsoft has done just that. As they launched *Halo 3* nearly a decade ago, they used a data-intensive approach to improving the game (Thompson, 2007). Through thousands of hours of tests, they were able to find where players struggled, where they were confused, where players had an unfair advantage, or where they simply got lost. They did this through observing players, but also recording their game play and analyzing visual and data summaries of where players were going and what they were doing.

In one example, they were able to look at a heat map (a map showing hotter colors where players spent more time and cooler colors where they spent less time) of game play to analyze where players were getting stuck. They were then able to change the terrain and the characters to alleviate this problem.

Now, analytics are an even more critical part of the game industry. In the age of "free to play" games (games that are free but you pay for upgrades, new levels, time savings, abilities, etc.), game companies want

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to know what tweaks to their games they can make to get more players to play, stick around, and spend money on those upgrades. So they look at volumes of data on what players are doing and what causes them to stick around and spend money. Sometimes this is done by looking at natural variation in patterns, but that approach is often combined with A/B testing, in which players may be randomly assigned two different conditions, and researchers look at the responses from the two conditions. For example, some players get a randomly assigned one-day wait for an upgrade to their virtual world, while other players get a two-day wait. Researchers can then examine whether the one-day or two-day wait led to more players paying for an upgrade.

With learning games, we are most interested in which patterns are associated with improved learning. Val Shute (Shute & Ventura, 2013) has done extensive work on a version of learning analytics in games she calls "Stealth Assessment." In one case she used a game called *Physics Playground* (originally *Newton's Playground*) to present learners with mechanics problems that they needed to solve by drawing various objects on the screen. For example, they might need to get a ball to a higher plane by drawing an inclined plane as well as a larger ball that might be used to knock it up the plane. All the students' actions in the game were logged, so when they drew a tool, used the tool, erased the tool, and so on, those actions were recorded. Other aspects such as time spent on task, time between moves, and so forth were also logged. Shute was able to show that the data taken from these logs were as predictive of players' physics knowledge as the formal tests that they took outside the game. This same technique has been applied by Shute and others in a variety of learning games, from 3D virtual worlds to role-playing games.

These analytics can be most useful when they are designed into the game from the start and focus on key insights that seem likely to be yielded from such data. As in many other fields, developers often decide to collect keystrokes or mouse clicks from their games rather than some higher-level action like completing the building of an item, or making a choice to go down a particular path. In these cases, you can still mine these data for interesting patterns through a process that our colleague Justin Reich (2013) calls "fishing in the exhaust." You can just look through and see if there are interesting patterns to be seen.

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But fishing in the exhaust is unlikely to answer any interesting design questions. There are just too many different patterns to be seen, and when you find them, you need to determine which of those patterns are interesting, that is, meaningful and generalizable, not just spurious correlations (Vigen, 2015). If the meaning is built in from the start, through a process like evidence-centered design or balanced design, then these correlations are much more likely to be meaningful. On the other hand, we should not entirely disregard the utility in understanding learning through such data streams. For certain kinds of outcomes, fitting data is available and can bring timely insights (Reich, 2014).

In our projects, we have used analytics in several ways. In the case of UbiqBio, we were able to look at play patterns and see how they correlated with success on external measures. Some of the very basics included how much time students played the various games.

The game requires a login and records how much time students spend actively involved in each game. Being "actively" involved is an important distinguishing factor, since this discounts time when the screen was just left on a page. This particular data set (figure 8.5) shows that the average (mean) amount of time spent playing each game varies quite a lot by

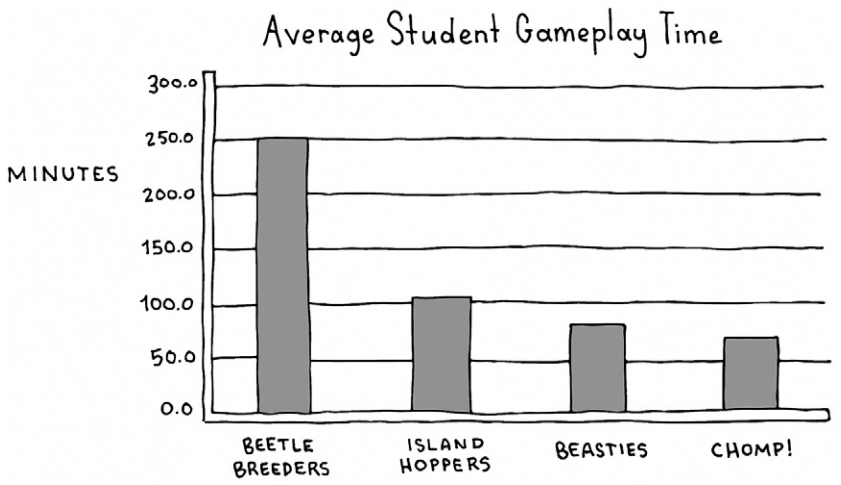

Figure 8.5
A graph showing the average student play time in some of the UbiqBio games (adapted from Perry & Klopfer, 2014)

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game, with *Beetle Breeders* being played four times as often as *Chomp!* was played.

Combining some of the analytics (data on both time spent and levels completed) with assessments (how well the players did on external assessments) provides interesting insights into the differences between the games and the relationship between design and outcomes (figure 8.6). In one game (*Beasties*), time spent playing was a predictor of performance, whereas in other games, time and level together (the first being positive and the second negative) were predictors of score (this essentially says students who spent less time completing the same number of levels did better). These kinds of data are trivial to collect from the games and provide insight into both student performance and game design.

In *Radix*, analytics were built in as an essential part of the research and feedback to both teachers and students. We recorded data that included general things like which quests were completed and in what order, where players went, and which items they collected. But we also collected information pertinent to particular quests, like which tools were used doing those quests, what the students "turned in" for their quests, and specifics of how they used the tools. This is a fair amount of data, but it is designed to be recorded in useful chunks. These are the actions that we felt were meaningful within the game. Clicking on a flower may not be meaningful, but turning in a flower for a quest had some meaning intended by the student.

For example, in one of the genetics questlines, players were required to collect flowers and breed them to produce particular kinds of offspring. To complete the quest, players needed to turn in the flowers that they had bred to exhibit the specified properties, as well as provide evidence of how

Coefficient Estimates for Play Time and Level Achieved on Test Score per Game

	Beetle Breeders	Beasties	Island Hoppers	Chomp!
Time (10K)	−.039**	.0647**	−.223**	x
Level	.245**	x	.0138**	x

Note: All models shown are statistically significant ($p < .05$). x = no statistically significant influence of that coefficient for that model. ** = significant difference at $p < .05$.

Figure 8.6
A table showing the relationship between performance gains, time played in the game, and the level achieved (adapted from Perry & Klopfer, 2014)

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they did this using a Punnett square. To understand not only whether they turned in the correct objects at the end, but also what process they used and how they revised their attempts, we can track these types of data:

- The genotype (genetic characteristics) and phenotype (visible traits) of the flowers they bred;
- Every attempt at creating the Punnett square and what they chose to put in it;
- Every use of tools to examine the genotype or phenotype of flowers and what they used it on;
- What they turned in when they tried to complete the quest, including the flowers and Punnett square.

In some of the questlines, specific detectors were built to identify patterns that we preidentified based on research. Often students have particular models in their heads of how systems work. By offering choices to express both the correct and the incorrect models of those systems, we can use analytics to identify the students who hold the incorrect models, and then offer those students alternate quests or relevant feedback based on their current state of understanding.

For example, in another questline around geometry concepts, players are required to draw scale maps. When players turn in their maps, we can determine specific mistakes like

- the correct scale but wrong map elements
- the wrong scale but correct map elements
- the correct scale but reversed in order

These could then help diagnose whether students were struggling with drawing geometric shapes (the first mistake), calculating scale (the second mistake), or converting units (the third mistake).

This combination of analytics makes it easy to show teachers where their students are succeeding and failing (figures 8.7 and 8.8).

But these analytics also provide the opportunity to gain additional insights into behaviors and performance. For example, we can identify patterns of behaviors within the game that are more likely to lead to success or failure of a quest. Or we might simply be able to see whether the game is successful at providing some of the choice that we would like to have in games. We don't want to create a game with one fixed pathway to a solution, but instead want one that has multiple pathways. Analysis by one

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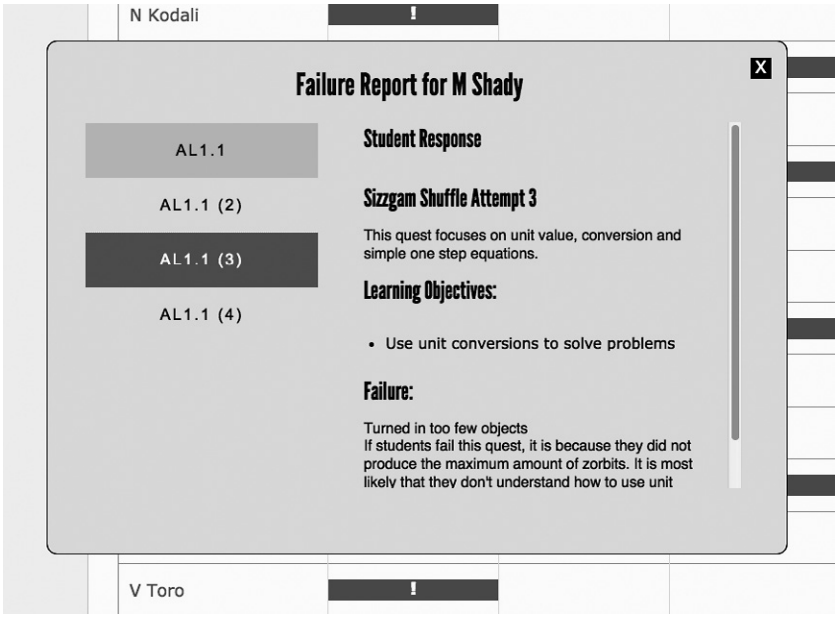
N Kodali
Failure Report for M Shady
AL1.1
AL1.1 (2)
AL1.1 (3)
AL1.1 (4)
Student Response
Sizzgam Shuffle Attempt 3
This quest focuses on unit value, conversion and simple one step equations.
Learning Objectives:
Use unit conversions to solve problems
Failure:
Turned in too few objects
If students fail this quest, it is because they did not produce the maximum amount of zorbits. It is most likely that they don't understand how to use unit
V Toro

Figure 8.7
A failure report indicating what a student has done based on analytics

of our colleagues, Montzy Cheng, did just that. She looked at the different tools that students chose for getting to a solution. Looking at one of the genetics quests and the tools that students used, she noted one highly successful pathway (figure 8.9) in which students used the examiner tool at least once and then bred the creatures. But there was another pathway in which the students didn't use the examiner, instead using the decoder and using it more times. This also led to success. These kinds of analytics can help us determine whether our designs are achieving the intended goals.

Context

All these metrics—artifacts, audience, affect, assessments, and analytics—are mediated by context. When was the game used? Where was it used? How was it used? We always seek to capture these data so that we can situate the findings within the right context. Often we think of our games as preparing students for future learning (Bransford & Schwartz, 1999),

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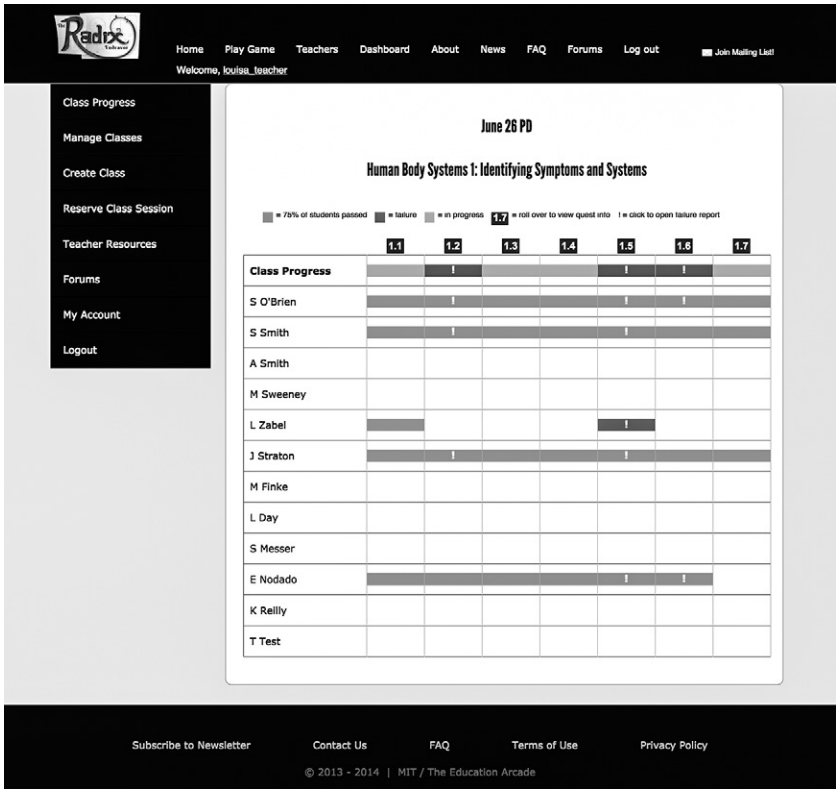

Figure 8.8
Dashboard showing student progress based on analytics

not necessarily teaching them the concept outright. For example, in one study (Arena & Schwartz, 2014) researchers designed a game called *Stats Invaders* to be used before students learned statistics. The idea was that students would develop some intuitions for statistics through playing the game that they could draw on when they learned the concepts formally. That study found that in fact the game did prepare students for this future learning.

Many of our games are built on this idea—that the game should come before the formal lesson, not as reinforcement. A great example of this was in *Celebrity Calamity*, in which our partners at Commonwealth ended up doing a small study. One group received a financial lecture first and then played the game, and another group played the game first and then had a

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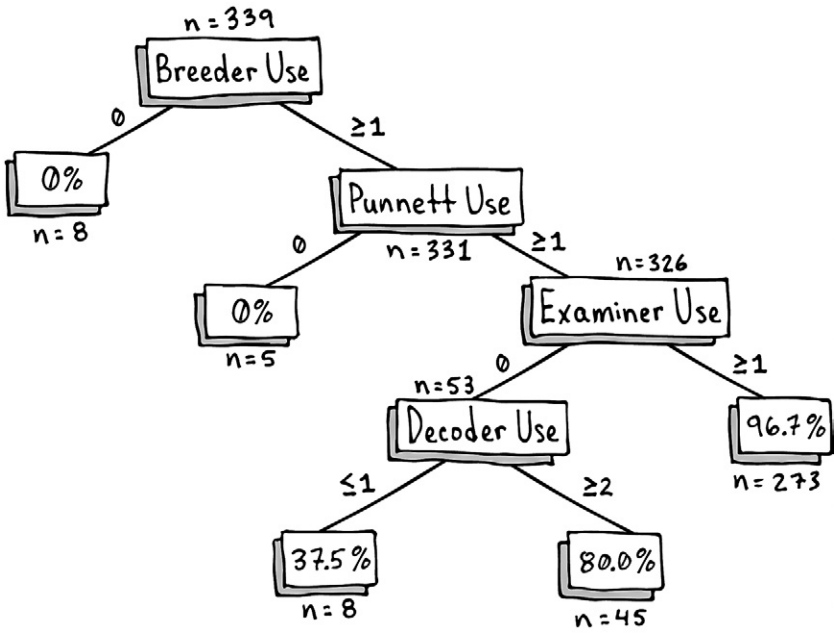

Figure 8.9
A tree showing different pathways of tools used to solve a quest (adapted from Cheng et al., 2017)

lecture. The Commonwealth team members tested the knowledge of each player in the middle (after only one activity) and again at the end (after both). They found that only the students in the group that played the game first, and then saw the lecture, improved their understanding. And for that group, only after doing both activities did they see improvement.

At a broader scale, the partnerships surrounding the Commonwealth games provide interesting examples of different contexts that contribute to substantially different outcomes. Partnerships that put the games in the right place at the right time (as measured by people who were primed for the message and with the ability to act immediately) had a substantial impact. In other cases, even when the game was played, if the context wasn't suitable for action, then there was no change.

So, when we implement games in the classroom, we track not just whether but how the games are being used. Is it used as homework or classwork? Before the unit or after the unit? Through observation or self-reporting teachers, we can also get information on what teachers did to

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support concepts in the game. Did they make direct reference to the game in a class lecture? Or provide a follow-up activity that related to the concepts in the game? While some of these variables help us determine how well the game worked, they also provide us with insights into where students and teachers like to use the games and how we might be able to change them to suit the classroom environment better.

Application

Applying these principles and techniques can be challenging. Each research project calls for a unique suite and application of methods and metrics. This holds true whether the project is embarking on research for the purpose of publication or simply to learn more about what is working or not working in a particular implementation. We do research when we are developing products, but we also embark on a less formal research process when we implement any games in classes to learn about how they are affecting students. This process enables us to improve the game design, implementation approach, and even outreach strategies for a game. Regardless of the nature of the research, in considering the methods to choose and how to apply them, it is important to consider several steps.

Plan in advance—There is a great temptation to rush into development and implementation, with the thought that research can be considered later. This temptation is especially strong in the day of big data, when you can collect every keystroke and figure out what it all means later. In practice, this purely post hoc research approach misses many of the most important insights. Those insights are revealed when you can identify meaningful actions based on theory, practice, or other empirical data.

Don't be seduced by numbers—Another mistake that is easy to make is to value quantitative data over qualitative data. After all, quantitative data can provide "answers." In fact, qualitative data may be more appropriate for some research scenarios, and, at the very least, qualitative and quantitative data can be complementary. Quantitative data can help answer the question of whether something happened or not (e.g., did students learn more using this game?), but they don't tell us why that result was obtained. Qualitative data (e.g., data from interviews, observations, or student responses) can help shed light on why that result was achieved. They can elucidate student thinking, motivation, and experience.

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Include diversity—No game works everywhere for everyone every time. But you won't be able to tease apart details of who it works for, and the context in which it works, without variation. Part of that variation can be intentional, as part of designed research, but natural variation is also important. This includes students, teachers, schools, implementation scenarios, and many other implementation variables. While you may think it is a better experiment to control these (and it may be at a late stage), early in a project, this variation can help bring insights into the conditions for success and failure.

Diversify your methods—Diversity of methods also matters. No single method will answer your questions completely. You will need to employ suites of methodologies and consider how they complement each other. Consider the qualitative methods that can answer the whys to your quantitative measures' whethers. Collect analytics data that may indicate actions that produce student artifacts of importance. Together these data can help triangulate findings that no single measure can.

Connect research and design—Most importantly, deeply and iteratively connect research and design. Research is not the same thing as evaluation—to determine whether something worked. Research can and should be formative: it can help shape the trajectory of design and development to lead to a better product. Design-based research (Brown, 1992) should be the backbone of learning games development. This methodology from the learning sciences promotes an iterative approach to design, development, and research, leading to better products and findings that help communicate why elements of the product are or are not working. Connecting research, design, and development makes this methodology more effective.

Connect research and implementation—There are many reasons that a game might succeed or fail in a classroom, only some of which are related to the game itself. The details of implementation are also critical for the success of the game. So research should also investigate the details of implementation. This includes information on what professional development was provided, the classroom materials that were used, and even the marketing messages to the intended audience. Documenting these factors so that they can be improved is also a key pathway to success.

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Resonating Research

Research on learning games is as complex as the design and development of these games. Good research is also equally as important as good design and development for the success of learning games. Research helps inform teachers, administrators, policymakers, and, most critically, the designers and developers themselves. Engaging seriously in this process has allowed us to not only develop products that we are proud of as products, but understand what is unique and interesting about them. It helps us abstract the details of what we are developing so that they are not just instances of games, but instances of ideas. The products may come and go, but the ideas behind them are what we expect to endure. They are what we hope resonates.

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9 Games not Gamification

Creating a game that resonates means keeping these principles that we've outlined in mind throughout the design process. And it means doing so in a serious way, not just checking a box that you've "created a strong narrative" or "made space for imagination." With that in mind, the principles that we have outlined are summarized below:

From *Labyrinth*:

• *The principle of cultivating player identity*—Trying on and exploring a new identity in a game space provides an opportunity for players to incorporate new aspects into their real-world identity.
• *The principle of scaling across time, space, and users*—Game experiences often become deeper and more meaningful when they are played over time, with people across distances, and with large numbers of other players.
• *The principle of preparing for future learning*—Experiences where players construct their own knowledge form a solid foundation for subsequent learning activities to build on.
• *The principle of deepening complexity*—Deep learning can be supported by designing levels or sequences of tasks that increase in complexity in interesting ways, challenging players to experiment further.
• *The principle of guiding reflection*—Explicit reflection activities facilitated by a mentor can illuminate how far players have come and solidify what they learned from and enjoyed about the game play.

From *Vanished*:

• *The principle of providing multiple pathways and freedom of effort*—Providing multiple entry points into a game experience, through choices in content or task, allows a feeling of autonomy and personalization.

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• *The principle of social design for learning*—Game features and implementation strategies can both create social connections around a game that encourage players to collaborate and learn from each other.
• *The principle of narrative and imaginative cocreation*—Weaving a strong and imaginative narrative throughout a game experience is one way to engage players and foster creativity by leaving space for them to participate in that fiction.
• *The principle of providing authentic problems*—Creating realistic settings in which to use the target skills motivates students to solve problems and helps them value those skills.

From *Radix*:

• *The principle of designing systems for exploration*—Games based on systems with interesting relationships that provide meaningful choices for players necessitate experimentation and analysis and interpretation of the outcomes.
• *The principle of working within an educational system*—School districts and other educational systems must be taken into consideration in the design of any game that will function within that system. Games that are designed thoughtfully and flexibly will be more accessible and easily adopted.
• *The principle of providing professional development*—Teachers using innovative games that involve alternative pedagogies need training, support, and access to peer communities o effectively implement those games.
• *The principle of making curricular connections*—Skills and practices, not only content knowledge, can be taught within games in unique ways. Drawing out these goals explicitly in bridge curriculum activities can build on and solidify the learning.
• *The principle of creating a culture of inquiry*—An inquiry-based game must be supported by a culture of inquiry in the surrounding educational setting. The expectations set outside the game influence players' sense of ownership and motivation inside the game.

From UbiqBio:

• *The principle of integrating into everyday life*—Games that are designed to fit into the spaces of players' lives can be woven into their daily activities and real-world experiences.

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• *The principle of connecting data to practice*—With training and practice, teachers can use game data to inform their classroom practice in beneficial ways.
• *The principle of designing adaptive experiences*—Task sequences that adapt difficulty and content based on player actions can engage and scaffold in valuable ways.
• *The principle of codesigning with educators*—Bringing teachers into the design process early and often leads to a more grounded and usable final product.

From *Farm Blitz* and *Bite Club* with Commonwealth:

• *The principle of working with the right partners*—Game projects benefit from partners that fit the projects' goals and provide complementary expertise.
• *The principle of facilitating lifelong learning*—Considering design elements specific to lifelong learners will make the game more relevant and more accessible to players outside school.
• *The principle of fostering communities of practice*—Communities of practice for players, educators, and even designers can greatly benefit the process but must be supported intentionally.
• *The principle of applying skills to daily life*—Both game features and curricular materials work together to demonstrate authentic context and tie game play to real-world situations.

If we think of these principles each time we design a game, why then do we create such different games? The examples that we have provided here are really quite varied, ranging from short casual games like *Farm Blitz* to long-form games like *Radix* and even games that blur the boundary between game and life like *Vanished*. Across these cases, learning goals and context vary.

Consider *Vanished*. The goal of *Vanished* was to promote scientific thinking and discourse among middle school students outside school in partnership with museums. So there was a goal (promoting scientific thinking and discourse), an audience (middle school students), and a context (outside school/connections with museums). Some principles rose to the top fairly quickly from these constraints. The *principle of social design for learning* was necessary to address the goal of student discourse. Slightly less obvious, perhaps, the *principle of narrative and imaginative cocreation* also quickly became a central pillar of this design. Engaging middle school students over

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a sustained period is a challenge, particularly when this is done outside school. So a narrative with prompts to spark students' own imaginations provides a hook and a way to sustain the engagement over time.

Other principles were important as well, though not all were of equal prominence. We considered principles concerning inquiry, connectivity, partnerships, and codesign, for example, fairly regularly, but they were not as prominent as the social construction of knowledge, which was absolutely critical. On the other hand, some characteristics of the project made it easy to ignore or significantly deemphasize some principles. Being an outside school intervention, principles of professional development and curricular connections were of much lower importance. Working with middle school students, the notion of lifelong learning was not as relevant either. Ultimately, we had a core set of guiding principles that we heavily emphasized, many more that were relevant but not of the prominence of the guiding principles, and a few that were irrelevant or significantly reduced in relevance. We wound up with a variable emphasis on the principles as applied in this particular game that might be visualized as seen in figure 9.1.

In contrast, consider *Radix*, a game that also had scientific thinking as one of its goals but without the emphasis on discourse per se. *Radix* was a game for high school students delivered primarily in school. It also had some specific curricular goals related to biology and math content, as well as a goal of enabling students to experiment with scientific systems like players do in many MMOs.

So while there was some overlap of desired learning outcomes, the combination of constraints and goals resulted in a different emphasis and resulting design. The *principle of designing systems for exploration* was of high importance, relating directly to the MMO systems that we wanted players to be able to experience. Since *Radix* was being used in schools, *making curricular connections* and *working within educational systems* were important principles we needed to follow. The depth of the game and the unfamiliar genre to many teachers required us to emphasize the *principle of providing professional development*.

While a few of the principles, like the *principle of applying skills to everyday life*, were of lower importance, the scale and scope of *Radix* required calling on most of the other principles in its design. Still, not all the principles can be of equally high importance. We need to establish a few as critical

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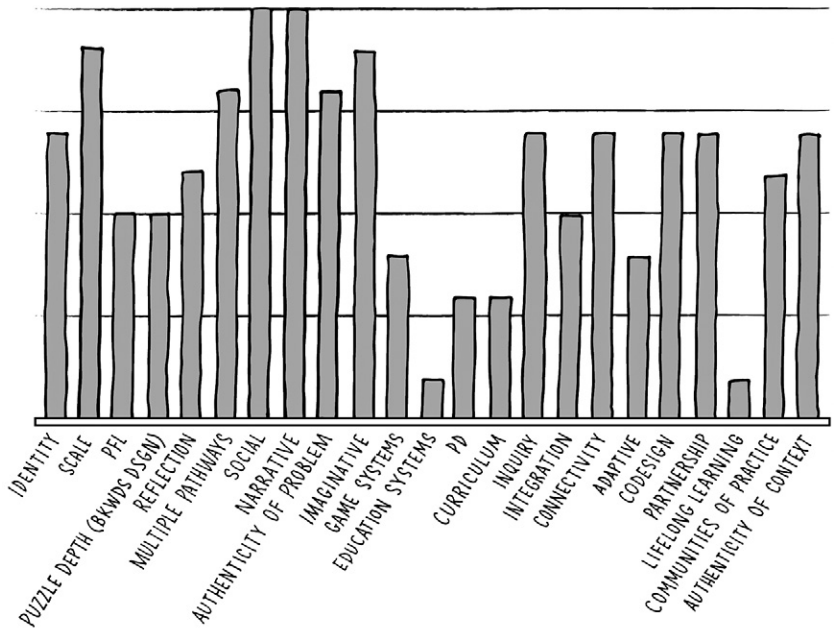

Figure 9.1
A sample scale showing the relative importance of the resonant games principles as applied in a given game, such as *Vanished*

pillars to the design, with others playing an important but supporting role. If everything is critical, the project can quickly grow in scope and spiral out of control. So in contrast to *Vanished*, our emphasis may have looked something like the comparison shown in figure 9.2.

The numbers represented here aren't exact, but the figure shows that depending on the project, we really need to look to some principles as central guides and others in a supporting role. The way we emphasize these principles steers the design of each game. There is no one right way to weigh the principles for a particular project. And there is an art to this balance as well as a science. The keys to establishing an effective balance are rapid prototyping, frequent play-testing, and design-based research that enables the calibration of these principles for the particular goals and audience. It would certainly be possible to create an interesting MMO that would hit similar goals as *Vanished*, or an ARG for schools that could teach

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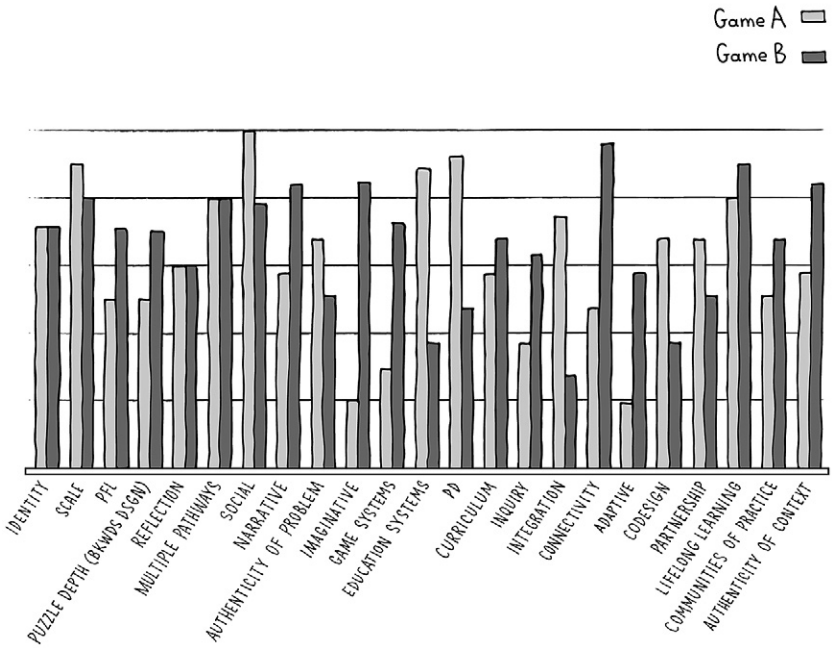

Figure 9.2
A comparison of the relative importance of each of the different principles in two games, *Radix* and *Vanished*

content and scientific thinking skills like *Radix*. Though it might be hard to create a single-player casual game for either of these.

So the principles and even the weighing of those principles don't provide a fixed formula for creating the perfect educational game. Games are "designed experiences" (Squire, 2006), which means that game play and outcomes are very much tied to the players and their experience both inside and outside the game. That combination is so widely variable that we can't possibly try to boil it down to a simple formula. But what we can do is focus design on productive practices and processes. And we can also design playful environments that provide the freedom to explore, the freedom to fail, freedom of identity, and freedom of effort. Thinking about the principles in this way does guide the design process significantly. But the educators and designers still need to design the experience.

This variation also has lessons for development. Over the years, we have been asked numerous times either to develop or to participate in a

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conversation about the development of "the" educational game platform. Given the diversity of genres of games, kinds of interesting data, ways of structuring interactions, and contexts of implementation, there is no way to create a single platform to cover the necessary productive variations. Even "the web" is too narrow, as games may be on smartphones, VR devices, or any number of new forms of digital interaction.

Promises and Perils

If the educational game platform isn't the next frontier, then what is? And where else are the pitfalls that we should avoid? Educational games have made some remarkable inroads in the last decade. A 2014 survey (Takeuchi & Vaala) of K–8 teachers in the United States found that nearly three quarters of the teachers used digital games in their classrooms. Granted some of these uses are trivia games for basic recall, but the widespread usage suggests a much broader acceptance for games as a part of learning than we saw a decade ago. But there is still work to be done to get to a place where meaningful games are broadly used as a regular part of practice in a way that resonates with both teachers and students. We see seven big areas that are both demanding innovation and providing opportunities in the coming years—research, funding, partnerships, distribution, data, platforms, and ungamification.

Research

There is a need for both more research and new kinds of research. The results of this book are based on years of design-based research. This methodology is a cornerstone of the field of educational games. We need to iteratively and methodically design, build, test, and refine our products to make sure they meet the requirements of the communities in which they are to be integrated, as well as the goals of the designers. But sometimes shortcuts are taken to get a product to market. We can't shortcut this process and need to take the research seriously.

At the same time, there is a demand for "rigorous" research of what works in education, as we discuss in chapter 8. We should fulfill this demand as well, which requires innovative ways of thinking about research methods. While the research should be rigorous, it can't just follow the methodologies from other domains like medicine. As seen in the recent reproducibility

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crisis in psychology, experiments involving human thought and interaction are notoriously difficult to replicate (Open Science Collaboration, 2015). Instead of seeking the perfect experiment from which we can prove the worth of a particular intervention, we should instead be creating interesting series of experiments, each of which offers unique insights into what is or is not working about a game in a given context with a specific population. From these kinds of data, achieved through mixed-method research, we will learn not only about the particular product of study, but also about some more general principles that can be applied to other products.

Research should guide continuous improvement and help create guidelines for implementation. For example, in our research on *Radix* we collected data about student scores on tests. But along with these data, we collected data about teacher implementation, student usage patterns, and context for the activities. By controlling this study more thoroughly, we would have missed out on interesting research questions about context (for example, where in the lesson sequence teachers used the game), and we would have needed to enforce an implementation regime that may not have worked when teachers actually got to choose.

As a field we need to advance our research methodologies, thinking about new kinds of data that we can collect (e.g., in game analytics) and what kinds of questions we want answered with those data (e.g., where and when will students play mobile math games, or what is the role of narrative in short-form science games). Ultimately these kinds of research questions can help define and refine the kinds of principles that we have outlined here.

Funding

Funding for the development of educational technologies is a complex and dynamic landscape. Many advances in educational technologies have come from research labs and universities. Federal funding through the National Science Foundation and the US Department of Education are primary among the funding sources for this work.

The challenge with this kind of funding is that it is designed to promote innovation and research, but not sustain products. So when a lab creates a game or other educational technology, the funding will support the development, implementation, and research, but once the funding has run out

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after a few years, there are no means to support the product. That means no training, technical support, or updates for changes in platforms. It is challenging for teachers to be able to rely on products without that kind of support.

On the other side, there is a new wave of startups in the educational technology space. There are incubators devoted to educational technologies in many communities (including Learn Launch here in Boston). The challenge here is that innovative and transformative products take a long time to make money, and the venture capital–funded startup space doesn't give these products much time to turn revenue positive. What often results in these spaces are pivots to products and services that fit more easily with the existing set of constraints, or collapse. Look at some of the heavily funded efforts like Zynga and New School Venture Fund's Co.Lab, which has now folded after a few years (with some successes along the way), or GlassLab at EA games, which has moved primarily away from game development to instead provide services and infrastructure for educational technology deployment.

The challenge is that neither model alone allows for significant innovation as well as revenue and sustainability. Another alternative is a hybrid approach, in which research labs and industry can partner, with the former taking on the role of risk taking and innovation, while the latter keeps an eye on what will actually sustain a product. We document one such venture in *The More We Know* (Klopfer & Haas, 2012). That book documents a collaboration between our group at MIT and NBC News on an online learning portal initially focused on games. The venture was a success in some regards, as it led to an ongoing learning venture from NBC News, but it was a failure in that the portal does not use games. Still there are lessons to be learned there, and more opportunities for such partnerships to experiment could potentially lead to greater success.

The federal government has also recognized the need for both spurring innovation and encouraging transfer out of universities and into companies that can maintain and grow these efforts. Through federal programs like Small Business Innovation Research and Small Business Technology Transfer, several federal agencies support work in the educational games space, funding partners such as Filament Games, with whom we worked on *Radix*. Another program, I-Corps, addresses another issue around university research spinoffs, which is training researchers to think like businesspeople.

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There are a lot of potential bottled up inside research universities and nonprofits, which can lead to products, but they need the resources and personnel to help with that transfer.

Distribution

The funding challenge is connected in many ways to the challenge of distribution. For games to have an impact, they need to reach their intended audience. In some cases, like most of the games discussed here, that is a matter of getting teachers and students to know about and use the games. But most research grants don't cover marketing as a line item. While many distribution and messaging channels may be free or cheap on the Internet, effective marketing through these channels is difficult and requires resources. We should not expect good ideas to just spread virally; they need to be crafted and curated. Distribution also often requires a personal touch, making connections face to face and with communities spread around the country. That requires additional effort and resources that often aren't covered by funding.

The most challenging part of distribution in the precollege market is that it is highly decentralized. While a few states such as Texas have centralized purchasing of textbooks, most marketing of software is done district by district, school by school, or even teacher by teacher throughout the United States. That makes distribution a significant challenge without a marketing network. This is one of the reasons why textbook distributors have held on to their market position. They have developed and maintained massive networks that retain marketing capability despite their product lagging in many ways. In a recent conversation with a venture capitalist investing in education, when he was asked about the K–12 market, he flat out said that he avoids that market, and sticks with the home, professional, and postsecondary markets because of the inherent complexities in K–12.

There are a few success stories in this space. Discovery Education, Brain Pop, and even NBC News, as well as a few others, have managed to build successful digital education businesses. But the challenges are numerous, and work needs to be done. There is a lot of interest in centralized marketplaces, that can be the "app store for education." Edmodo, Google, and others have tried with varied amounts of success. Many smaller platforms currently exist. Perhaps such a platform could spread if supported by an independent entity.

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For actual success, the platform needs to be accompanied by policy. Purchasing and budgeting provide additional challenges to widespread distribution. Software that serves narrow purposes (perhaps for only one subject or even one topic) is difficult to purchase in a market set up for all-encompassing textbooks. While it would be wonderful to provide all these services for free to schools, that model is rarely compatible with sustainability. We need support and innovation for business models that can succeed in marketing and sustaining products.

Partnerships

We discuss many aspects of partnerships in this book, including partnerships with developers, museums, nonprofits, corporations, and schools. There are more partnerships to be found in the future. Some of those might be with marketing and distribution partners, as discussed in the previous section. Yet other partners might provide insights and innovations for the next generation of learning games. There is currently a great deal of interest in cognitive science and what research in this domain might be able to contribute to learning. In turn, cognitive scientists are quite interested in the data and insights that can be generated by well-designed learning games. Early forays (and follies) in "brain training" like Lumosity aside, there is a connection to be made.

We don't think that the all the answers to design are held in analyzing brain scans, nor do we believe that the tightly controlled experiments of cognitive science will translate to the broad range of conditions found in real schools. But we do think that insights can be learned from this field, and that we can contribute complementary insights in return.

Similarly, there are many aspects of computer science that show great possibilities for game design. Artificial intelligence has long been a part of game design, creating non-player characters (NPCs) that respond in natural ways and provide continuous challenge. There is much more to be explored, perhaps identifying not just right and wrong ways of solving problems in games, but identifying why answers are right and wrong so that the player can be given specific remediation and subsequent challenges. Natural language processing is still fairly rudimentary but may soon be able to create an interface with a much richer set of inputs from players.

In these cases, the greatest benefits will come not from simply appropriating research from these other fields, but by creating collaborations with

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them. Learning can be bidirectional and lead to advances in both game design and the corresponding domains.

Data

While data and data science can be thought of as yet another field with which to collaborate, they are so important (and somewhat nuanced) that they deserve special attention. We discuss in this book ways in which we've used data from our games. We've tried to understand where players are succeeding and failing in *Radix*, teacher usage patterns in UbiqBio, and what marketing works in our partnership with Commonwealth.

These methods are only scratching the surface of what we can do with data. Some designers take the perspective that games should just generate a lot of data, and we will be able to make sense of it with data mining after the fact. This kind of "fishing in the exhaust" (Reich, 2013) may occasionally offer interesting glimpses, but without a priori theory and well-designed experiences, the best that they can offer is conjecture. The most useful insights will come from games that carefully design experiences to create meaningful data trails. That was what we did in *Radix*, creating quests with series of actions that tell us not only what students have done, but what they understand as they accumulate more data. This gives us a better picture of their systems understanding, not just their mastery of facts.

Designing experiences this way is challenging and resource intensive. As we better understand the data and how we can use them, we may in turn be able to both design better experiences and do so with greater ease. Platforms like Adage (Halverson & Owen 2014) aim to accomplish this. By providing a common platform for collecting, storing, and analyzing data, designers can offload some of that work to common frameworks. There is still much more to be done in this area, and researchers in data science, visualization, education, human-computer interactions, and game design all need to collaborate to use data in significant ways.

Platforms

Schools are constantly chasing hardware platforms. Since computers have entered the consciousness of schools, educators have paid more attention to the hardware than to the software. Computer labs, teacher computers, laptop carts, tablets, and Chromebooks have all had their phases, and today one can find many schools engaging in any and all of these. And many

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schools are seeing a mixture because of bring-your-own-device (BYOD) policies, which allow students to choose a device to bring with them. Overcoming the challenges disseminating to schools means figuring out the platform challenge as well. But tablets, laptops, and phones are fundamentally different. And new platforms coming down the road also have new affordances.

While there is a lot of discussion about "mobile first" technology development strategies, which are designed primarily for mobile platforms, for educational products this means simply shrinking things down to the appropriate size. But truly "mobile first" design means accommodating for not only screen size but context for use, and ideally is enhanced by the affordances of mobile, rather than merely mitigating for the shortcomings. Take, for example, the UbiqBio games. These were designed to be played in short bursts of time and require simple actions, well suited to the mobile experience. While *Radix* could be shrunk and ported to a phone platform, it wouldn't work well without a lot of adaptation. Instead what we've thought about is a companion app that might allow you to do *Radix*-related tasks on your phone between full *Radix* sessions. As many students from middle school up consider their phones their primary platform, there is a lot of opportunity to do more, and more interesting activities on that platform.

The choice of platform can make or break an experience. For many years we developed mobile participatory simulations, first on custom wearable computers (Collela, 2000) and later on some of the early PDAs of the time, like Palm Pilots (Klopfer et al., 2005). Through the use of these technologies, a whole class became a decentralized simulation. In the most well known of these examples, everyone in the class had a PDA with a character on it. They could go around and "meet" other players by using the short range (line of sight and about one foot) infrared communication abilities of these devices. Eventually some people would get "sick," and the mission then became to figure out how and why.

This kind of simulation was very popular with teachers because they could use novel digital technologies to address complex issues, but they could facilitate the activities in a familiar way. As wireless and mobile technologies progressed, we tried to recreate this platform on smartphones and tablets, but have continually struggled. While the proliferation of devices and the ease of networking makes the technical aspects of these

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simulations easier to create, the shift from short-range to long-range communication capabilities has fundamentally changed the nature of these activities. Short-range communication required face-to-face interactions; long-range communication does not. Redesigning around these new platform affordances requires fundamentally rethinking the mechanics of these games in the context of the platform to create the desired classroom dynamics.

Now we are starting to see the rise of virtual reality (VR) and augmented reality (AR) platforms. The Oculus, Vive, and Hololens are emerging, along with other new platforms. In some ways, simply experiencing 3D content with one of these VR or AR platforms is very exciting. But here, too, transformative learning experiences will only come when designers figure out how to take advantage of the unique aspects of these platforms. Early efforts to create immersive field trips or port 3D games show the potential of these platforms, but they also show that we have a long way to go before we really take advantage of them.

Seeking more advanced high tech is not necessarily the pathway to success. There is a resurgence in interest in lower tech as well. Board, card, and role-playing games are seeing an increase in popularity with both players and designers. On-demand game production sites and crowdfunding have brought a lot of interest to these neglected game forms. There is a lot of innovation happening now, and opportunities to create games that embody many of the principles we've defined without the technical challenges of digital games.

The bottom line with any of these platforms, though, is that the same principles we've outlined here hold true. While the technology may introduce new ways in which the principles can be applied, the basics of design, partnerships, and implementation remain the same.

Ungamification

Many of the trivialized elements of games have now become pervasive throughout our daily experiences. We see points, leaderboards, and achievements in everything from exercise applications to online learning to monitoring of daily habits. These "gamified" applications are based on the principle that these game elements will make these tasks fun and motivate people to persist. It is our assertion that while this may be true in the short term, in most cases, this kind of feedback doesn't teach an appreciation for

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the underlying activity, and in the long run will be counterproductive, as the activity will not persist without the accompanying reward.

We believe that the principles we've outlined here can be applied in many contexts to activity design, and that many kinds of educational activities can benefit from their application. This application needs to be done with thought and care, baked into the design from the start, not simply layered on to other activities after the fact. We certainly encourage these principles to be adopted and adapted in many applications. But it should be done in a way that can carefully consider how to apply a whole set of principles to the experience.

Looking Forward

For better or worse, the hype cycle has passed in the world of educational games. We actually believe that this is mostly for the better. It allows people to focus on what is great about this medium and design meaningful experiences. And we can now set reasonable expectations as to what to expect.

There is still a huge opportunity in front of us. Technology is improving and making exciting new things possible. Independent game developers are providing exciting innovations in game design that can be applied in educational game design. And new markets are opening up to games, including nontraditional learners and international markets. While the hype has passed, the excitement has not.

The next wave of resonant games has the potential to resonate with a wider audience and make an even greater impact. Let's make it happen.

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